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**Technology Resource Document for the  
Assembled Chemical Weapons Assessment  
Environmental Impact Statement  
Volume 5: Assembled Systems for  
Weapons Destruction at Blue Grass Army Depot**

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**Environmental Assessment Division  
Argonne National Laboratory**



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Volume 5

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# **Technology Resource Document for the Assembled Chemical Weapons Assessment Environmental Impact Statement Volume 5: Assembled Systems for Weapons Destruction at Blue Grass Army Depot**

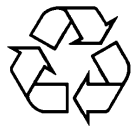
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## NOTATION

The following is a list of the acronyms, initialisms, abbreviations (including units of measure), and chemical formulas used in this document. Some acronyms used in tables or figures only are defined in the respective tables or figures.

### ACRONYMS, INITIALISMS, AND ABBREVIATIONS

ACW	assembled chemical weapons
ACWA	Assembled Chemical Weapons Assessment
ANAD	Anniston Army Depot
APG	Aberdeen Proving Ground
ASG	U.S. Army Surgeon General
ATP	Alternative Technology Program (development of chemical agent neutralization process)
BGAD	Blue Grass Army Depot
BIF	steam boiler or industrial furnace
BRA	brine reduction area (baseline post-treatment drum drier equipment)
BRT	batch rotary treater
BSRM	burster size reduction machine
CAA	Clean Air Act
CAMDS	Chemical Agent Munitions Disposal System
CatOx	catalytic oxidation
CBDCOM	U.S. Army Chemical and Biological Defense Command
CFR	Code of Federal Regulations
COINS	Continuously Indexing Neutralization System™
Composition B	a high explosive composed of 60% RDX, 39.5% TNT, and 0.5% calcium silicate (referred to as Comp B)
CRS	condensate recovery system
CST	continuous steam treater
CSTR	continuously stirred tank reactor
CTF	chemical transfer facility
CWA	Clean Water Act
CWC	Chemical Weapons Convention
DCD	Deseret Chemical Depot
DFS	deactivation furnace system (baseline furnace consisting of a rotary retort and a heated discharge conveyor [HDC])
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation

DPE	demilitarization protective ensemble (highest level of chemical agent personal protective equipment)
DPG	Dugway Proving Ground
DRE	destruction removal efficiency
DSHS	dunnage shredder/hydropulper system
ECBC	Edgewood Chemical Biological Center
ECR	explosion-containment room
EDS	engineering design study
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERDEC	U.S. Army Edgewood Research, Development, and Engineering Center
ERH	energetics rotary hydrolyzer
FIRE	Factor Information Retrieval
FTE	full-time equivalent
GPCR	Gas-Phase Chemical Reduction™
HAP	hazardous air pollutant
HDC	heated discharge conveyor (baseline electric radiation tunnel furnace)
HEPA	high-efficiency particulate air (type of air filtration system)
HMA	hot mix asphalt
ICB	Immobilized Cell Bioreactor™
JACADS	Johnston Atoll Chemical Agent Disposal System
LLNL	Lawrence Livermore National Laboratory
LEL	lower explosive limit
LPG	liquefied petroleum gas
M121A1	projectile, 155 mm, chemical agent (GB or VX)
M23	land mine, 13-in.-diameter and 5-in.-high munition filled with VX
M28	propellant grain (M55 rocket)
M2A1	cartridge, 4.2 in., chemical agent (HD or HT)
M417	M55 rocket fuze
M426	projectile, 8 in., chemical agent (GB or VX)
M55	rocket, 115 mm, chemical agent (GB or VX)
M56	warhead, 115-mm rocket, chemical agent (GB or VX)
M60	cartridge, 105 mm, chemical agent (H or HD)
M60	rocket, 115 mm, inert
M61	rocket, practice 115 mm, simulant (EG)
M104	projectile, 155 mm, chemical agent (H or HD)
M110	projectile, 155-mm, chemical agent (H or HD)
MDB	Munitions Demilitarization Building



MMDM	modified multipurpose demilitarization machine (baseline reverse assembly equipment)
MPF	metal parts furnace (baseline tunnel furnace for drained munitions bodies)
MPT	metal parts treater
MRSM	modified rocket shear machine
NCD	Newport Chemical Depot
NEPA	National Environmental Policy Act
NRC	National Research Council
ONC	on-site container
PBA	Pine Bluff Arsenal
PCD	Pueblo Chemical Depot
PM <sub>10</sub>	particulate matter with a diameter less than or equal to 10 micrometers
PMACWA	U.S. Department of Defense, Program Manager for Assembled Chemical Weapons Assessment
PMCD	U.S. Army, Program Manager for Chemical Demilitarization
PMD	projectile/mortar disassembly (baseline reverse assembly equipment)
POTW	publicly owned treatment works
PRH	projectile rotary hydrolyzer
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine (a high explosive)
RFP	request for proposal
ROD	record of decision
RSM	rocket shear machine (baseline reverse assembly equipment)
Schedule 2	chemical agent precursors listed in Schedule 2 of the Chemical Weapons Convention (CWC)
SCWO	supercritical water oxidation
SDS	spent decontamination system
TAP	toxic air pollutant
TC	ton container
TNT	2,4,6-trinitrotoluene (a high explosive)
TOC	total organic carbon
TOCDF	Tooele Chemical Agent Disposal Facility
TOX	toxic cubicle
TRBP	thermal reduction batch processor
TRD	technical resource document
TW	transpiring wall
UMDA	Umatilla Depot Activity
1X, 3X, 5X	U.S. Army system for material safety hazard classification (X, XXX, and XXXXX, respectively)

**CHEMICAL FORMULAS**

Al(OH) <sub>3</sub>	aluminum hydroxide
CaN <sub>2</sub> O <sub>6</sub>	calcium nitrate
CEES	chloroethyl ethyl sulfide
CH <sub>4</sub>	methane
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
FeSO <sub>4</sub>	ferrous sulfate
GB	sarin (nerve agent), O-isopropyl methylphosphonofluoride
H	undistilled sulfur mustard, bis(2-chloroethyl)sulfide
HCl	hydrogen chloride
HD	distilled sulfur mustard, bis(2-chloroethyl)sulfide
HF	hydrogen fluoride
H <sub>2</sub> O	water
H <sub>2</sub> O <sub>2</sub>	hydrogen peroxide
H <sub>2</sub> S	hydrogen sulfide
H <sub>2</sub> SO <sub>4</sub>	sulfuric acid
H <sub>3</sub> PO <sub>4</sub>	phosphoric acid
HT	blister agent, mustard agent (H) with T
K <sub>2</sub> HPO <sub>4</sub>	dipotassium sulfate
KOH	potassium hydroxide
LN <sub>2</sub>	liquid nitrogen
LOX	liquid oxygen
MgCl <sub>2</sub>	magnesium chloride
N or N <sub>2</sub>	nitrogen
Na <sub>2</sub> CO <sub>3</sub>	sodium carbonate
NaOCl	sodium hypochlorite (supertropical bleach, household bleach)
NaOH	sodium hydroxide
NH <sub>3</sub>	ammonia
(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>	ammonium phosphate
NH <sub>4</sub> OH	ammonium hydroxide
NO <sub>x</sub>	nitrogen oxides
O or O <sub>2</sub>	oxygen
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
SO <sub>2</sub>	sulfur dioxide
SO <sub>x</sub>	sulfur oxides
TNT	2,4,6-trinitrotoluene (a high explosive)
VOC	volatile organic compound
VX	methylphosphonothioic acid (nerve agent)

**UNITS OF MEASURE**

acfm	actual cubic foot (feet) per minute
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atm	atmosphere(s)
°C	degree(s) Celsius
cm	centimeter(s)
d	day(s)
°F	degree(s) Fahrenheit
ft	foot (feet)
ft <sup>3</sup>	cubic foot (feet)
gal	gallon(s)
g	gram(s)
GW	gigawatt(s)
GWh	gigawatt hour(s)
h	hour(s)
ha	hectare(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
kW	kilowatt(s)
L	liter(s)
lb	pound(s)
M	molar
m	meter(s)
m <sup>3</sup>	cubic meter(s)
mg	milligram(s)
mi	mile(s)
min	minute(s)
mL	milliliter(s)
mm	millimeter(s)
MMBtu	million British thermal units
MW	megawatt(s)
MWh	megawatt hour(s)
MPa	megapascal(s)
ppb	part(s) per billion
ppm	part(s) per million
psia	pound(s) per square inch, absolute
s	second(s)
rpm	revolution(s) per minute
scf	standard cubic foot (feet)
t	metric ton(s)
ton	short ton(s)
wt%	weight percent
yd <sup>3</sup>	cubic yard(s)
yr	year(s)

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**TECHNOLOGY RESOURCE DOCUMENT  
FOR THE  
ASSEMBLED CHEMICAL WEAPONS ASSESSMENT  
ENVIRONMENTAL IMPACT STATEMENT**

**VOLUME 5:  
ASSEMBLED SYSTEMS FOR WEAPONS DESTRUCTION  
AT BLUE GRASS ARMY DEPOT**

by

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**5.1 INTRODUCTION**

**5.1.1 DOCUMENT PURPOSE**

This volume of the Technical Resource Document (TRD) for the *Environmental Impact Statement (EIS) for the Design, Construction and Operation of One or More Pilot Test Facilities for Assembled Chemical Weapons Destruction Technologies at One or More Sites* (PMACWA 2001g) pertains to the destruction of assembled chemical weapons (ACW) stored in the U.S. Army's unitary chemical stockpile at Blue Grass Army Depot (BGAD), located outside Richmond, Kentucky. This volume presents technical and process information on each of the destruction technologies applicable to treatment of the specific ACW stored at BGAD. The destruction technologies described are those that have been demonstrated as part of the Assembled Chemical Weapons Assessment (ACWA) selection process (see Volume 1).

It should be noted that some options for establishing ACWA pilot-scale facilities at specific installations are highly unlikely. However, no judgment regarding the feasibility or practicality of establishing a pilot-scale facility at a specific installation is expressed in this TRD.

**5.1.2 THE ASSEMBLED CHEMICAL WEAPONS ASSESSMENT PROGRAM  
AT BLUE GRASS ARMY DEPOT**

The U.S. Department of Defense (DOD) Program Manager for Assembled Chemical Weapons Assessment (PMACWA) defines ACW as munitions containing both chemical agents

and energetic materials (e.g., propellants, explosives) that are stored in the U.S. unitary<sup>1</sup> chemical weapons stockpile. Such devices include rockets, projectiles and mortars, and land mines.<sup>2</sup> Unitary agents include chemical blister agents (i.e., the mustard agents H, HD, and HT) and chemical nerve agents (i.e., GB [sarin] and VX) (Chemical and Biological Defense Command [CBDCOM 1997]). GB, VX, and H and related compounds are listed as hazardous wastes in Kentucky, and the destruction facility would be permitted under federal and state hazardous waste laws. Volume 1 of this TRD provides background information on the agent and energetic components of ACW.

Each of the stockpile installations stores a different combination of individual types or configurations of ACW. Different or modified component treatment technologies are often required for the diverse ACW types or configurations maintained at the various stockpile locations. Thus, a technology or unit that can be applied to one type or configuration of ACW may not be applicable to another type or configuration. This volume of the TRD provides specific information for destruction of ACW at BGAD.

The original ACW unitary stockpile contained approximately 31,500 tons (28,576 t) of unitary agents (Pacoraro 1999, as cited in NRC 1999) stored in a variety of ACW and bulk containers (e.g., ton containers [TCs]). In addition to BGAD, stockpile locations in the continental United States include Aberdeen Proving Ground (APG), Maryland; Anniston Army Depot (ANAD), Alabama; Newport Chemical Depot (NCD), Indiana; Pine Bluff Arsenal (PBA), Arkansas; Pueblo Chemical Depot (PCD), Colorado; Deseret Chemical Depot (DCD), Utah; and Umatilla Depot Activity (UMDA), Oregon.<sup>3</sup> ACW were also stored at the Johnston Atoll Chemical Agent Disposal System (JACADS) facility; however, ACW destruction at JACADS has been completed. The ACW at the Tooele Chemical Agent Disposal Facility (TOCDF) at DCD are currently being destroyed through the baseline incineration process. This process, as defined by the U.S. Army Program Manager for Chemical Demilitarization PMCD (1988), has undergone a number of improvements since its initial implementation. Baseline incinerator systems are currently being constructed at other stockpile locations, specifically, at PBA, ANAD, and UMDA. Only bulk agent containers are stored at APG and NCD; nonincineration-based destruction facilities are planned for these installations.

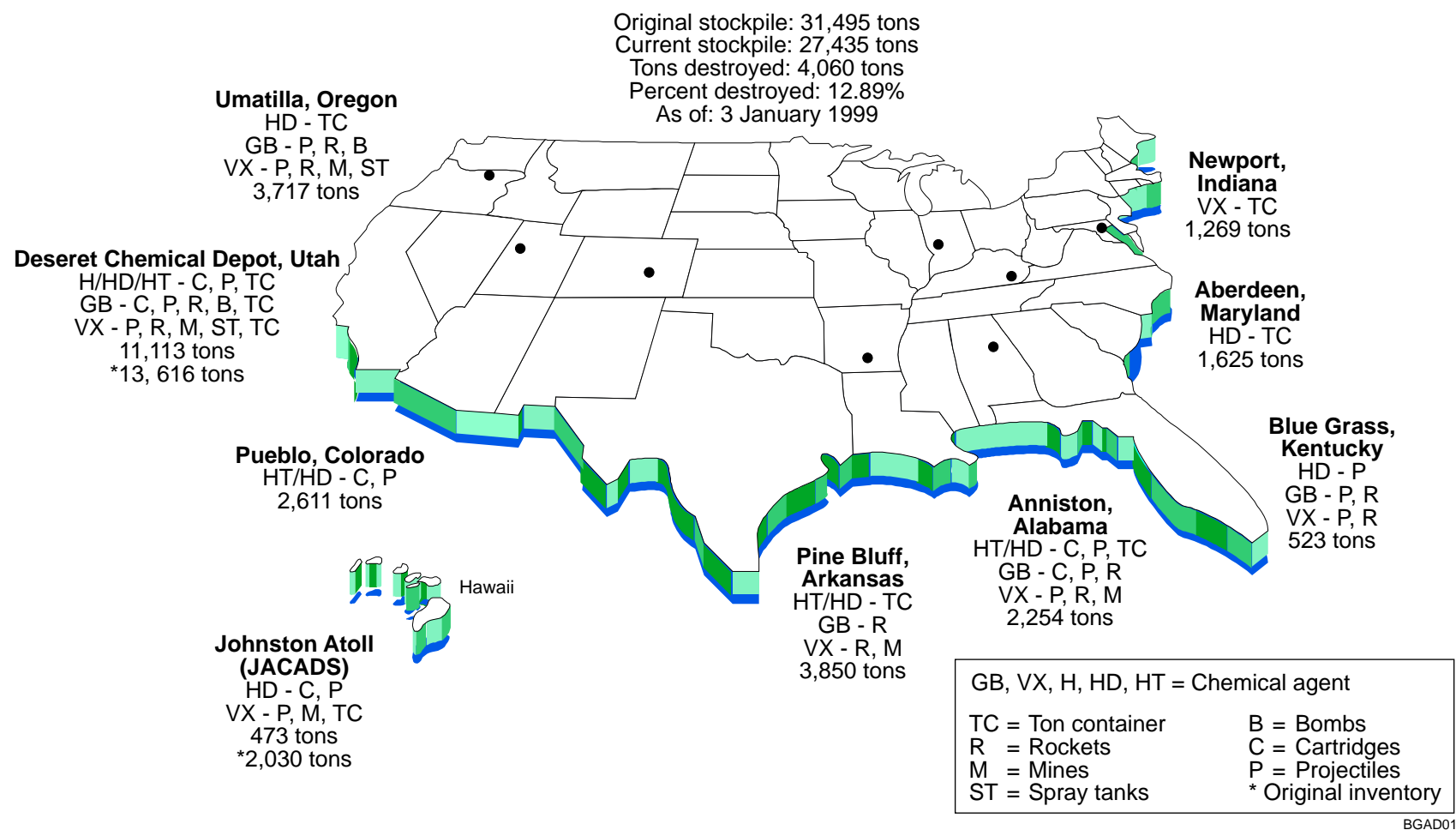
Figure 5.1 identifies all the unitary stockpile locations. Table 5.1 provides an inventory (as of November 1999) of the various types of chemical munitions in storage at these installations, including BGAD.

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<sup>1</sup> The term “unitary” refers to the use of a single hazardous compound (i.e., chemical agent) in the munitions. In contrast, “binary” chemical weapons use two relatively nonhazardous compounds that are mixed together to form a hazardous or lethal compound after the weapon is fired or released.

<sup>2</sup> Mortars are often defined as a type of cartridge or projectile.

<sup>3</sup> These installations store both ACW and chemical agents in bulk (e.g., TCs). Chemical agents stored in bulk are not considered ACW and are not addressed under the ACWA program.



**FIGURE 5.1** Types of Agent, Quantities of Agent, Types of Munitions, and Percentage of Total Agent Stockpiled at Each Storage Site (Source: Pacoraro 1999, as cited in NRC 1999) (Note: The information presented in this figure represents the stockpile as of January 3, 1999. Since that time, destruction of the inventory at JACADS has been completed, and much of the inventory at Deseret Chemical Depot has been destroyed.)

**TABLE 5.1 Chemical Munitions Inventory by Stockpile Location<sup>a,b</sup>**

Agent	Item	Anniston Army Depot		Deseret Chemical Depot	
		No. of Munitions	Agent (lb)	No. of Munitions	Agent (lb)
H	155-mm projectiles	c		54,663	639,540
HT	4.2-in. cartridges	183,552	1,064,600	62,590	363,020
HD	4.2-in. cartridges	75,360	452,160	976	5,860
HD	105-mm cartridges	23,064	68,500		
HD	155-mm projectiles	17,643	206,420		
GB	105-mm cartridges	74,014	120,640	119,400	194,620
GB	105-mm projectiles	26	40	679,303	1,107,260
GB	155-mm projectiles	9,600	62,400	89,141	579,420
GB	8-in. projectiles	16,026	232,380		
GB	M55 rockets	42,738	457,300	28,945	309,720
GB	M56 rocket warheads	24	260	1,056	11,300
VX	155-mm projectiles	139,581	837,480	53,216	319,300
VX	8-in. projectiles			1	20
VX	M55 rockets	35,636	356,360	3,966	39,660
VX	M56 rocket warheads	26	260	3,560	35,600
VX	Mines	44,131	463,380	22,690	238,240
L	Ton containers			10	25,920
HD	Ton containers	108	185,080	6,398	11,383,420
HT	Ton container				
GA	Ton containers			2	2,820
TGA <sup>d</sup>	Ton containers			2	1,280
TGB <sup>d</sup>	Ton containers			7	6,960
GB	WETEYE bombs			888	308,140
GB	500-lb bombs				
GB	750-lb bombs			4,463	981,860
GB	Ton containers			5,709	8,598,200
VX	Spray tanks			862	1,168,880
VX	Ton containers			640	910,960



TABLE 5.1 (Cont.)

Agent	Item	<u>Blue Grass Army Depot</u>		<u>Pine Bluff Arsenal</u>	
		No. of Munitions	Agent (lb)	No. of Munitions	Agent (lb)
H	155-mm projectiles				
HT	4.2-in. cartridges				
HD	4.2-in. cartridges				
HD	105-mm cartridges				
HD	155-mm projectiles	15,492	181,260		
GB	105-mm cartridges				
GB	105-mm projectiles				
GB	155-mm projectiles				
GB	8-in. projectiles	3,977	57,660		
GB	M55 rockets	51,716	553,360	90,231	965,480
GB	M56 rocket warheads	24	260	178	1,900
VX	155-mm projectiles	12,816	76,900		
VX	8-in. projectiles				
VX	M55 rockets	17,733	177,340	19,582	195,820
VX	M56 rocket warheads	6	60	26	260
VX	Mines			9,378	98,460
L	Ton containers				
HD	Ton containers			107	188,400
HT	Ton container			3,591	6,249,100
GA	Ton containers				
TGA <sup>d</sup>	Ton containers				
TGB <sup>d</sup>	Ton containers				
GB	WETEYE bombs				
GB	500-lb bombs				
GB	750-lb bombs				
GB	Ton containers				
VX	Spray tanks				
VX	Ton containers				

**TABLE 5.1 (Cont.)**

Agent	Item	<u>Pueblo Chemical Depot</u>		<u>Umatilla Chemical Depot</u>	
		No. of Munitions	Agent (lb)	No. of Munitions	Agent (lb)
H	155-mm projectiles				
HT	4.2-in. cartridges	20,384	118,220		
HD	4.2-in. cartridges	76,722	460,340		
HD	105-mm cartridges	383,418	1,138,760		
HD	155-mm projectiles	299,554	3,504,780		
GB	105-mm cartridges				
GB	105-mm projectiles				
GB	155-mm projectiles			47,406	308,140
GB	8-in. projectiles			14,246	206,560
GB	M55 rockets			91,375	977,720
GB	M56 rocket warheads			67	720
VX	155-mm projectiles			32,313	193,880
VX	8-in. projectiles			3,752	54,400
VX	M55 rockets			14,513	145,140
VX	M56 rocket warheads			6	60
VX	Mines			11,685	122,700
L	Ton containers				
HD	Ton containers			2,635	4,679,040
HT	Ton container				
GA	Ton containers				
TGA <sup>d</sup>	Ton containers				
TGB <sup>d</sup>	Ton containers				
GB	WETEYE bombs				
GB	500-lb bombs			27	2,960
GB	750-lb bombs			2,418	531,960
GB	Ton containers				
VX	Spray tanks			156	211,540
VX	Ton containers				

<sup>a</sup> Information on items appearing below the dashed line (including ton containers, bombs, and spray tanks) is provided for information purposes only. Although considered part of the unitary stockpile, these items are not ACW.

<sup>b</sup> The chemical munitions inventory at JACADS is not included in this table because destruction of this inventory has been completed.

<sup>c</sup> A blank indicates that the item is not included in the inventory at that location.

<sup>d</sup> The “T” before GA and GB stands for “thickened.”

The unitary stockpile at BGAD consists of projectiles that contain HD, GB, and VX, and M55 rockets and warheads that contain GB and VX. Projectiles stored at BGAD include one type of 155-mm projectile filled with H/HD (M110), one type of 8-in. projectile filled with GB (M426), and one type of 155-mm projectile filled with VX (M121A1). Rockets stored at BGAD include M55 rockets filled with either GB or VX, and M56 rocket warheads filled with either GB or VX. The energetics in these ACW are limited to those present in projectiles and rockets.

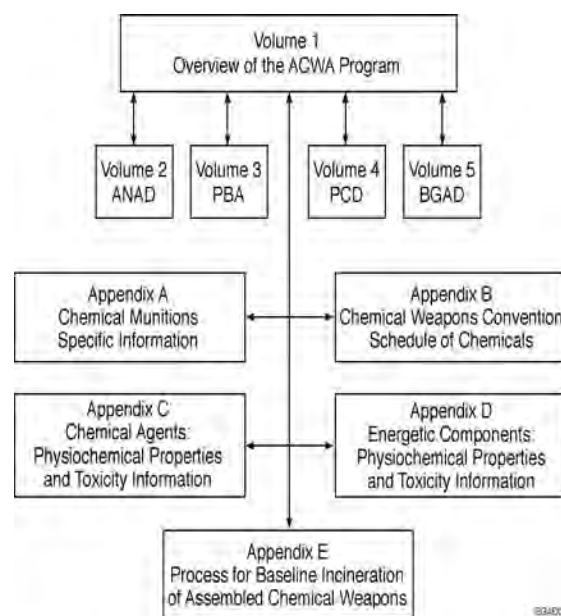
BGAD is similar to ANAD in that its stockpile consists of both mustard agents (H/HD) and nerve agents (GB and VX). However, unlike ANAD, no land mines are stored at BGAD. Overall, the quantity of chemical agent stored at BGAD accounts for 1.6% by weight of the total U.S. stockpile. This is the smallest inventory among the U.S. Army's eight continental U.S. storage sites.

Table 5.2 identifies the types of projectiles and rockets stored at BGAD and their agent and energetic components. Volume 1 of this TRD contains more detailed descriptions of the ACW types and their components.

### 5.1.3 ORGANIZATION OF TECHNICAL RESOURCE DOCUMENT

This document provides primary support for an EIS that evaluates alternative weapons destruction technologies for pilot-scale testing at ANAD, PBA, PCD, and BGAD, in compliance with the National Environmental Policy Act (NEPA) (PMACWA 2000b). This TRD consists of five volumes (see Figure 5.2). Volume 1 provides general information on the ACWA program; a description of the ACW, including chemical and energetic components; an overview of the ACWA technology selection process; and a summary of each of the ACWA system treatment technologies. Volume 1 also includes five supporting appendixes. Volume 2 pertains to ANAD; Volumes 3 and 4 pertain to PBA and PCD, respectively; and this volume, Volume 5, pertains to BGAD.

Section 5.2 of this volume identifies and describes each of the technologies that could be used to treat the ACW stored at BGAD for each of the six process categories (munitions access, agent treatment, energetics treatment, dunnage treatment, metal parts treatment, and effluent management and pollution controls). Following a brief introduction, the history of each technology system is reviewed. Then, a general process overview is provided, the results of demonstration testing and engineering design studies are discussed, and a detailed process



**FIGURE 5.2 Organization of Technical Resource Document**

**TABLE 5.2 Chemical Munitions Inventory at BGAD**

Munition	Number in Storage <sup>a</sup>	Length <sup>b</sup>	Weight <sup>b</sup>	Agent Amount <sup>b</sup>	Burster Type	Burster Amount <sup>b</sup>	Propellant Type	Propellant Amount <sup>b</sup>	Fuze Type	Fuze Amount <sup>b</sup>
155-mm projectile M110 HD-filled	15,492	26.8 in.	42.9 kg	5.3 kg	Tetrytol	0.19 kg	None	None	c	c
155-mm projectile M121A1 VX-filled	12,816	26.8 in.	44.9 kg	2.7 kg	Comp B4	1.1 kg	None	None	c	c
8 in. projectile M426 GB-filled	3,977	8 in.	90.3 kg	6.6 kg	Comp B4	3.2 kg	None	None	c	c
Rocket M55 GB- or VX-filled	51,716 17,733	1.98 m	25.9 kg	4.9 kg GB 4.5 kg VX	Comp B or tetrytol	1.5 kg	M28 <sup>d</sup>	8.7 kg	M417 (RDX)	11.9 g
Rocket warhead M56 GB- or VX-filled	24 6	NA <sup>e</sup>	NA	4.9 kg GB 4.5 kg VX	Comp B or tetrytol	1.5 kg	None	None	M417 (RDX)	11.9 g

<sup>a</sup> Number in storage represents data as of July 11, 1997.

<sup>b</sup> Conversions: 1 in. = 2.54 cm; 1 lb = 0.454 kg.

<sup>c</sup> 155-mm projectiles are stored with lifting rings in place of fuzes.

<sup>d</sup> M28 propellant consists of 60% nitrocellulose, 23.8% nitroglycerine, and 9.9% triacetin.

<sup>e</sup> NA = data not available.

Source: Compilation of information presented in Appendix A of Volume 1 of this TRD and Appendix A of NRC (1999).

description is presented.<sup>4</sup> For all the described systems, technologies common to other systems are also identified, as are possible technology combinations that can be employed to create different, but viable, systems.

Section 5.3 of this volume provides supplemental information for pilot testing assembled systems. Included are facility descriptions, system inputs and resource requirements, routine emissions and wastes, and activities and schedules. This section also addresses both construction and operation of the facility.

Section 5.4 of this volume contains a list of references that were used in preparing this volume. The technology provider reports included in this list (General Atomics 1999, Parsons/Allied Signal 1999, Foster Wheeler/Eco Logic/Kraerner 2000, AEA/CH2MHILL 2000) contain more detailed information on the ACWA technologies.

<sup>4</sup> The descriptions are based on the equipment used by the technology providers during the ACWA demonstrations (General Atomics 1999, Parsons/Allied Signal 1999, Foster Wheeler/Eco Logic/Kvaerner 2000, AEA/CH2MHILL 2000). The equipment that may eventually be used in a pilot-scale facility may vary, depending on the system that is actually employed and system refinements. However, conceptually, the equipment used in a pilot-scale facility would be similar to that evaluated during the demonstration test phase of the ACWA program.

## 5.2 ASSEMBLED SYSTEMS FOR WEAPONS DESTRUCTION AT BLUE GRASS ARMY DEPOT

Four ACWA technology systems are presently under consideration for pilot-scale testing at BGAD.<sup>5</sup> These systems and their corresponding processes are as follows:

- Primary destruction: agent and energetics neutralization; secondary destruction: supercritical water oxidation (SCWO) (demonstrated by General Atomics<sup>6</sup>). This system is referred to herein as neutralization/SCWO.
- Primary destruction: agent and energetics neutralization; secondary destruction: biological treatment (demonstrated by Parsons/Honeywell<sup>7</sup>). This system is referred to herein as neutralization/biotreatment.
- Primary destruction: agent and energetics neutralization, and gas-phase chemical reduction (GPCR<sup>TM</sup>); secondary destruction: transpiring-wall supercritical water oxidation (TW-SCWO) (demonstrated by Foster Wheeler/Eco Logic/Kvaerner). This system is referred to as neutralization/GPCR/TW-SCWO.
- Primary destruction: electrochemical oxidation via the SILVER II process (demonstrated by AEA/CH2MHILL). The technology provider indicates that no secondary treatment is needed. This system is referred to as electrochemical oxidation.

The neutralization/SCWO system is a viable technology system for treating ACW containing mustard or nerve agent. The neutralization/biotreatment system is viable only for ACW containing mustard agents. Both of these technology systems were demonstrated during Demonstration I (Demo I) of the ACWA demonstration test program. The latter two technologies, neutralization/GPCR/TW-SCWO and electrochemical oxidation, were demonstrated during Demonstration II (Demo II) of the ACWA demonstration test program. These technology systems are amenable to treating ACW containing mustard or nerve agent.

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<sup>5</sup> The technology system descriptions presented in this TRD were derived from data and information developed by technology providers during the PMACWA demonstration test phase for the ACWA program (PMACWA 1999a; 2001b,c). The use of technology provider names and nomenclature from demonstration documentation (General Atomics 1999, Parsons/Allied Signal 1999, Foster Wheeler/Eco Logic/Kvaerner 2000, AEA/CH2MHILL 2000) does not imply endorsement of a specific technology provider.

<sup>6</sup> General Atomics refers to its ACWA system as the General Atomics Total Solution (GATS).

<sup>7</sup> Honeywell purchased Allied Signal in early 2000; General Electric purchased Honeywell in 2000. Parsons/Honeywell refers to its ACWA system as the Water Hydrolysis of Explosives and Agent Technology (WHEAT) process.

As indicated in Volume 1 of this TRD, incineration is not a candidate technology in the EIS that this resource document supports. The baseline incineration process is being considered as a potential destruction technology at BGAD under a separate EIS (PMCD 2000). Although incineration is not a candidate ACWA technology, the four ACWA technologies discussed above employ one or more components of the baseline incineration process (e.g., reverse assembly, pollution abatement system). Elements of the baseline incineration process are therefore included in the overview of the baseline and ACWA system technologies provided in Volume 1 of this TRD (Section 1.4). In addition, the baseline incineration process is described in more detail in Appendix E of Volume 1.

Table 5.3 provides an overview of the baseline incineration process and the ACWA technology systems being considered for BGAD. A more detailed description of each of the ACWA technology systems follows.<sup>8</sup> This document is based on a conceptual “full-scale” facility as defined in the PMACWA Request for Proposal (RFP) for the ACWA program (CBDCOM 1997). Exact specifications of units and processes, including operating temperatures and pressures, may vary.

### 5.2.1 NEUTRALIZATION/SCWO

The neutralization/SCWO technology system consists of neutralization of agents and energetics and secondary treatment of neutralization residuals using SCWO. This technology system, proposed by General Atomics,<sup>9</sup> is applicable to all ACW stored at BGAD, including ACW containing nerve or mustard agent. It uses a solid-wall SCWO process. Operation of a TW-SCWO unit is discussed in Section 5.2.3. The following subsections provide a more detailed discussion of the technologies and processes involved in this system. The technology provider’s technology demonstration report (General Atomics 1999) may be viewed for additional detail.

#### 5.2.1.1 Process Overview

The neutralization/SCWO process, as applied to projectiles and rockets stored at BGAD, is summarized in Figure 5.3. As Figure 5.3 illustrates, a modified baseline reverse assembly process would be used to disassemble ACW at BGAD, with some differences for projectiles versus rockets. For projectiles, the energetic materials would be removed, and the agent would

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<sup>8</sup> Monitoring of emissions is part of any environmental waste management scenario. Monitoring of ACW treatment processes will be prescribed in environmental permits issued under the federal Resource Conservation and Recovery Act (RCRA). Monitoring methodologies are not specifically described in this TRD.

<sup>9</sup> Neutralization is a common element of three of the four technology systems discussed in this volume of the TRD.

**TABLE 5.3 Technology Overview for Baseline Incineration and ACWA Technology Systems for BGAD<sup>a</sup>**

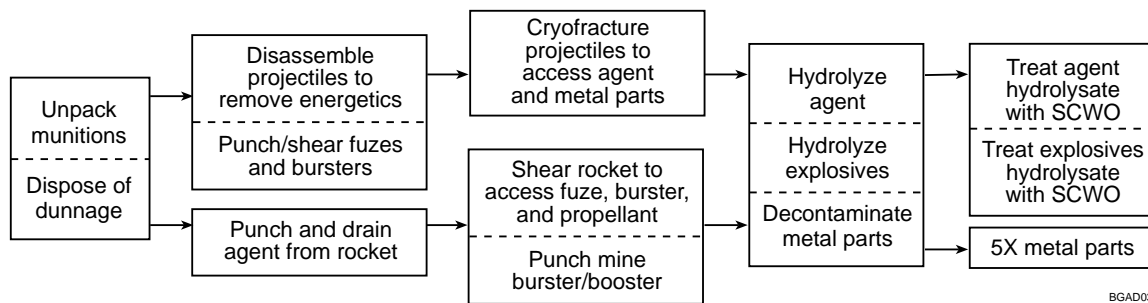
Technology	Munitions Access	Agent Treatment	Energetics Treatment	Metal Parts Treatment	Dunnage Treatment
Baseline Incineration	Baseline reverse assembly	Liquid incinerator (LIC) (a stationary LIC)	Deactivation furnace system (DFS) (a rotary kiln incinerator), with heated discharge conveyor (HDC)	Metal parts furnace (MPF) (a roller hearth incinerator)	Size reduction and stationary bed incinerator
Neutralization/ SCWO	Parts of baseline reverse assembly, cryofracture	Hydrolysis <sup>b</sup> followed by SCWO	Caustic hydrolysis followed by SCWO	Caustic hydrolysis followed by thermal treatment with steam	Size reduction/ pulping followed by SCWO
Neutralization/ Biotreatment <sup>c</sup>	Modified baseline reverse assembly (fluid-abrasive cutting and fluid-mining)	Hydrolysis <sup>b</sup> followed by biotreatment	Caustic hydrolysis followed by biotreatment	Thermal treatment with steam	Size reduction/ thermal treatment with steam
Neutralization/ GPCR/TW-SCWO	Modified baseline reverse assembly (uses baseline process with modified equipment)	Hydrolysis <sup>b</sup> followed by TW-SCWO	Caustic hydrolysis followed by TW-SCWO	Caustic hydrolysis and spray washing followed by GPCR using hydrogen and steam	GPCR using hydrogen and steam
Electrochemical oxidation	Modified baseline reverse assembly (fluid-abrasive cutting and fluid-mining)	Electrochemical oxidation using SILVER II process	Electrochemical oxidation using SILVER II process	Detonation chamber and thermal treatment with steam	Size reduction followed by thermal treatment with steam

<sup>a</sup> Combinations of these technologies may also be considered.

<sup>b</sup> Nerve agents are treated using caustic hydrolysis; mustard agents are treated using water hydrolysis followed by a caustic wash.

<sup>c</sup> Biotreatment is viable for mustard agents only.

Source: Adapted from PMACWA (1999a; 2001b,c).



**FIGURE 5.3 Overview of the Neutralization/SCWO Process (General Atomics System) for the Treatment of ACW at BGAD (Source: Adapted from NRC 1999)**

be accessed. In the system proposed by General Atomics, this would be accomplished by cryofracturing the munition.<sup>10</sup> The cryofracture process is not part of the baseline system. For rockets, the baseline system would be used. Agent would first be accessed using a punch and drain process. Then the rocket would be sheared to access the fuze, burster, and propellant. The HD and the nerve agents GB and VX would then be neutralized/hydrolyzed with water (for HD) and sodium hydroxide (NaOH) (for GB and VX) in systems operated at 194°F (90°C) and atmospheric pressure;<sup>11</sup> energetics would also be neutralized/hydrolyzed with a NaOH solution, in systems also operated at 194°F (90°C) and atmospheric pressure. Neutralization of HD and HT using water would be followed by a caustic wash using NaOH. Dunnage would be shredded, micronized, hydropulped, and neutralized/hydrolyzed. Resulting hydrolysates would then be treated in separate SCWO units. Dunnage hydrolysate would be added to energetics hydrolysate and treated in the same SCWO unit. Thermal treatment would be used to treat metal parts to a 5X condition.<sup>12</sup>

### 5.2.1.2 History of Destructive Processes

Neutralization and SCWO are the primary destructive processes employed in this technology. The history of these processes is summarized below.

<sup>10</sup> Cryofracture is a system whereby materials are cooled rapidly, usually by immersion in liquid nitrogen. This embrittles the materials such that they may be easily fractured in a subsequent process.

<sup>11</sup> This unit is not operated under pressure.

<sup>12</sup> The definition of 5X is provided in Volume 1 of this TRD (see Section 1.2.2.4). While materials treated to a 5X condition may be released for unrestricted use (e.g., recycling), materials determined to be 3X must remain under government control. For example, hazardous waste disposal facilities may receive 3X waste.



### 5.2.1.2.1 Neutralization of Agent and Energetics

Agent neutralization and energetics neutralization by hydrolysis are discussed in detail in a 1999 National Research Council (NRC) report (Appendixes D and E, respectively) (NRC 1999). The literature is extensive on neutralization of HD (NRC 1999). Technically, neutralization is a chemical reaction between an acid and a base to form a salt and water (NRC 1999). In this application, neutralization refers to a hydrolysis reaction in which a target compound is reacted with water, an acid, or a base to break chemical bonds in the target compound (NRC 1999). Chemical demilitarization literature, therefore, often uses neutralization and hydrolysis as interchangeable terms for the same process (NRC 1999).

Neutralization by using hot water (194°F, 90°C), followed by the addition of a caustic (NaOH), is the process that will be pilot tested at APG for destruction of the bulk HD stored there (APG 1997). The NRC references work performed at the U.S. Army Edgewood Research, Development, and Engineering Center (ERDEC)<sup>13</sup> and indicates that neutralization has been shown to reduce HD concentrations in hydrolysate to less than 20 ppb (the analytical detection limit); 99% of the HD is converted to thiodiglycol (NRC 1999, ERDEC 1996). Thiodiglycol is a Schedule 2 compound (see Appendix B of Volume 1), and the hydrolysate requires further treatment to meet the requirements of the Chemical Weapons Convention (CWC) (NRC 1999). The neutralization reaction with water requires vigorous stirring because HD is relatively insoluble in water (NRC 1999; see also Appendix C of Volume 1). In addition, a semisolid or gelatinous “heel” of mustard agent can form in stored munitions. The heel, which can amount to up to 10% of the stored agent, can be washed out (NRC 1999). HD hydrolysates contain high levels of thiodiglycol, as explained previously and may also contain a high salt content, various metals, and chlorinated hydrocarbons (NRC 1999).

For energetics, this technology involves caustic neutralization using solutions of NaOH. The NRC reports that there is less experience with base neutralization of energetic materials relative to experience with chemical agents (NRC 1999). However, neutralization of energetics has been substituted for open burning/open detonation, a treatment that has historically been applied to these materials (NRC 1999). The open literature contains many references to caustic hydrolysis of energetics, dating back to the mid-1800s (NRC 1999). The Navy recently published a review of alkaline hydrolysis of energetic materials pertinent to ACW (Newman 1999, as cited in NRC 1999).

Base hydrolysis decomposes energetic materials to organic and inorganic salts, organic degradation products, and various gases (NRC 1999). The base used — typically NaOH, potassium hydroxide (KOH), ammonium hydroxide (NH<sub>4</sub>OH), or sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) — usually attacks all the functional groups of the energetic material (NRC 1999). While previous work with base hydrolysis involved studying reactions under ambient conditions, recent work has been conducted at elevated temperatures and pressures, which increases the solubility

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<sup>13</sup> Now known as the Edgewood Chemical Biological Center (ECBC).

of the energetics in solution, increases the reaction rate, and reduces clogging of the reactor vessel (NRC 1999). The reactions, however, are exothermic and must be carefully controlled and monitored to prevent an explosion (NRC 1999).

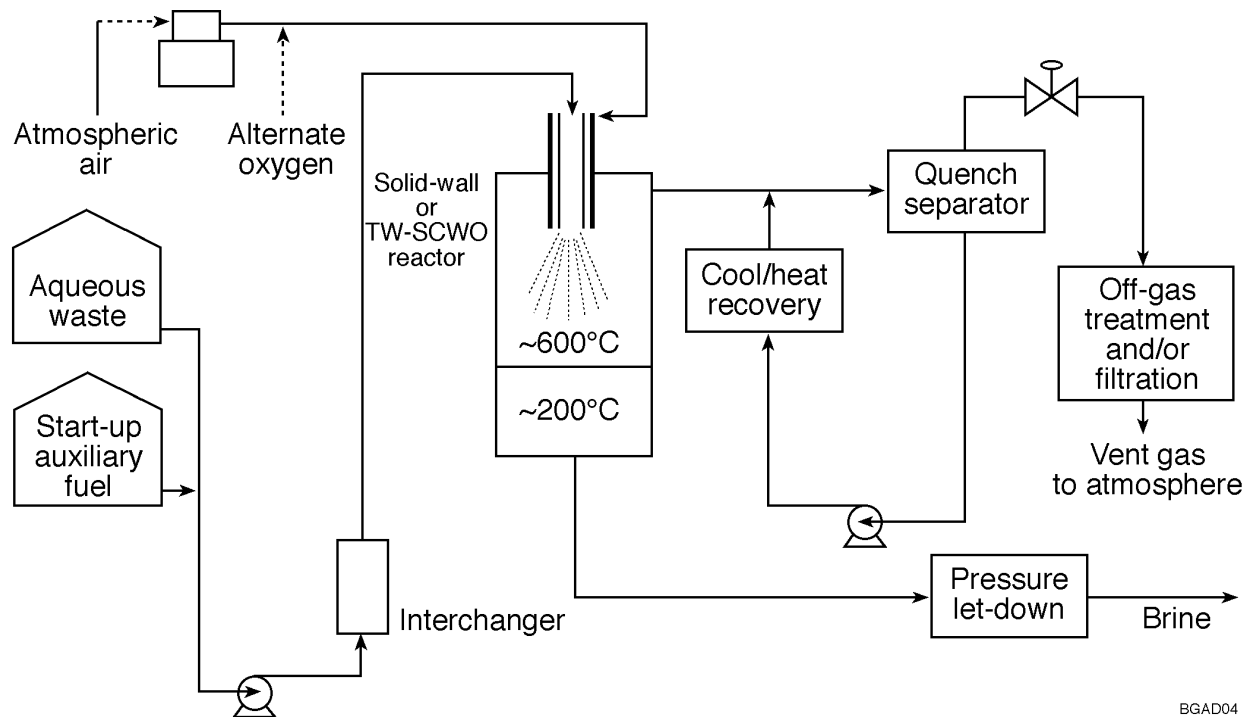
The NRC indicates that caustic neutralization of energetics is not a mature technology; nevertheless, it concludes that “the current level of understanding is, perhaps, sufficient to indicate that engineering practices can probably restrict the domain of possible reaction products” (NRC 1999). Products from the neutralization reaction may include nitrates, nitrites, ammonia, nitrogen, hydrogen, organic acids, and formaldehyde, as well as various salts (NRC 1999).

#### **5.2.1.2.2 Supercritical Water Oxidation**

The NRC reviews the SCWO process in Appendix F of its 1999 report. Much of the material in this appendix is based on a review of the SCWO technology for application to VX hydrolysates that the NRC performed in 1998 (NRC 1998). This work was conducted primarily in response to the proposed use of the SCWO technology for treating the VX hydrolysates resulting from neutralization of the U.S. Army’s bulk stockpile of VX at NCD, Newport, Indiana. Hydrolysis followed by application of SCWO is nearing the pilot-scale testing phase at NCD (PMCD 1998b, NRC 1999). The U.S. Army prepared an EIS of the hydrolysis/SCWO process proposed for treatment of bulk VX at NCD (PMCD 1998b) and concluded that the proposed facility would meet stringent permitting requirements of the Clean Water Act (CWA), the Resource Conservation and Recovery Act (RCRA), and the Clean Air Act (CAA). The U.S. Army further concluded that the site and environs of the facility would be affected by construction and pilot testing of the proposed facility, but that appreciable adverse human health and environmental impacts would be unexpected, and those that may occur would be well within regulatory limits (PMCD 1998b).

When using SCWO, the temperature and water pressure are raised to above supercritical conditions (705°F [374°C] and 3,204 psia [22 MPa]). Under these conditions, salts precipitate out of solution, and organic compounds are oxidized to carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O) (NRC 1999). Figure 5.4 is simplified process flow diagram for a typical solid-wall SCWO process.

SCWO is not widely used within the United States. The NRC reports that SCWO has been used on a pilot scale to treat other types of wastes, but that it is used commercially at only one location within the United States (NRC 1998, as cited in NRC 1999). Although SCWO has been under development for over 20 years, both in the United States and overseas, only recently have problems with the reactor vessel been overcome sufficiently to permit consideration of full-scale operations.



BGAD04

**FIGURE 5.4 Typical Flow Diagram for SCWO (Source: Adapted from NRC 1999)**

### 5.2.1.3 Demonstration Testing<sup>14</sup>

The neutralization/SCWO technology was demonstrated during Demo I of the PMACWA demonstration test program. Demo I testing was conducted in spring 1999. This section provides a summary of demonstration testing for neutralization/SCWO. Demo I testing results are provided in PMACWA (1999a).

Baseline reverse assembly, carbon filtration, the brine reduction area (BRA) operation, and other technologies employed in neutralization/SCWO were not evaluated during demonstration testing. The following unit operations proposed for neutralization/SCWO were not selected by the PMACWA for demonstration for the reasons given below.

Cryofracture System (bath, robotic transport, and press). This is a well-developed system that has been demonstrated at full scale at Dugway Proving Ground (DPG). For the ACWA program, the only required changes to the demonstrated equipment were scaling down the press and instituting conveyor transport of individual munitions through the liquid nitrogen (LN<sub>2</sub>) bath. Demonstration of this unit was therefore not required.

<sup>14</sup> This material was derived from PMACWA (1999a) and refers to demonstration testing during Phase I of the ACWA demonstration process. Because demonstration testing was intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

Projectile Rotary Hydrolyzer (PRH). Drum-dryers, the basis of the PRH, are well developed and have been demonstrated commercially. The PRH is essentially a batch process with a slow tumbling action (identical in principle to the energetics rotary hydrolyzer [ERH]). Therefore, demonstration of this unit was not considered critical.

Heated Discharge Conveyor (HDC). The proposed unit is essentially identical in design to the baseline HDC (used at TOCDF) but would operate in a nitrogen atmosphere. Heated bucket conveyors are well developed and have been demonstrated commercially. While demonstration of the HDC was originally planned, the discontinuation of testing of polychlorinated biphenyls (PCBs) made an HDC demonstration less essential at this stage in the program.<sup>15</sup>

Metal Parts Furnace (MPF). This batch furnace is similar to the baseline MPF structure except that induction heaters rather than gas-fired heaters are used. Operationally, the MPF differs from the baseline version because an inert atmosphere is used to process solid wastes. Demonstration of this unit was not required, since the MPF has been proposed to treat only surface-washed metal hardware with a low organic loading.

The reasons for selecting the neutralization/SCWO demonstration unit operations, testing objectives, and significant deviations from the planned demonstration testing are discussed in the following subsections.

#### **5.2.1.3.1 Agent Hydrolysis**

The U.S. Army previously demonstrated agent hydrolysis extensively as part of its Alternative Technology Program (ATP).<sup>16</sup> The PMACWA ran agent hydrolysis units primarily to provide representative feedstock for SCWO and to characterize the intermediate product stream for residual agent, Schedule 2 compounds, and other substances required to verify the mass balance. The specific test objectives of these demonstration units included the following:

- Design, fabricate, and deliver GB and VX hydrolysate production systems with the production capacity of 100 gal (379 L) of hydrolysate per run;
- Use the hydrolysate recipes developed and tested by the Edgewood Chemical Biological Center (ECBC).

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<sup>15</sup> PCBs were originally identified as a constituent of concern for the M55 rockets, because the rockets are stored in shipping/firing tubes made of an epoxy resin that can contain PCBs. PCBs were not evaluated during demonstration testing because regulatory approvals could not be obtained within the allotted timeframe. PCBs will be evaluated during pilot-scale testing.

<sup>16</sup> Water was tested in the ATP for HD, and caustic was tested for VX.

- Demonstrate that the agent concentration in the hydrolysate solution is less than the waste control limit by using the analytical methods developed and approved by the ECBC.
- Characterize solid, liquid, and gas process streams; and
- Provide agent hydrolysate in support of demonstration testing.

GB and VX hydrolysates were produced in a newly constructed 100-gal (379-L) stirred tank reactor system at the U.S. Army's Chemical Agent Munitions Disposal System (CAMDS) located at DCD in Utah. The design and manufacture of a hydrolysis system provided information on equipment and operational parameters that can be used for scale-up to a full-scale facility. Hydrolysate was shipped to DPG for use in the SCWO demonstration.

HD hydrolysate was produced at the chemical transfer facility (CTF) at APG. The equipment used was not intended to be a model for scale-up to a full-scale facility, but was an expedient design suitable for use in the contained environment of the CTF. HD hydrolysate was shipped to DPG for use in the SCWO demonstration.<sup>17</sup>

There were no significant deviations from the planned demonstration testing.

#### **5.2.1.3.2 Energetics Hydrolysis**

Other government agencies have previously evaluated energetics hydrolysis; however, further knowledge of the process was needed for evaluation, feedstock for SCWO was required, and characterization of the intermediate product streams for residual energetics and other substances was required to verify a mass balance. The specific test objectives of these demonstration units included the following:

- Produce energetics hydrolysate for use as feed material in subsequent demonstration testing;
- Characterize solid, liquid, and gas process streams; and
- Gather process operation information to support the ACWA program and future scale-up.

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<sup>17</sup> HT or T-mustard was not tested because the PMACWA determined that HT is similar enough to HD that demonstration results for HD can be applied to HT.

M28 propellant was hydrolyzed with 12% NaOH to produce hydrolysate in two production runs at the United States Radford Army Ammunition Plant, Radford, Virginia. Composition B and tetrytol were hydrolyzed using 12% NaOH in a single production run at the Pantex Plant, Amarillo, Texas. All of the hydrolysates were transported to DPG, Utah, and used as feedstock for the SCWO.

There were no significant deviations from the planned demonstration testing.

#### **5.2.1.3.3 Dunnage Shredder/Hydropulper System**

The dunnage shredder/hydropulper system (DSHS) was demonstrated to show that solid wastes (wooden dunnage, demilitarization protective ensemble [DPE]<sup>18</sup> suits, and butyl rubber) could be adequately size-reduced and pulped to a pumpable mixture. Shredded material was used for SCWO pulped dunnage testing. The objectives of the demonstration testing included the following:

- Validate the ability of the shredders and the hydropulper to adequately prepare the dunnage for downstream processing in the SCWO;
- Qualitatively evaluate the operability of the shredder/hydropulper unit operations with particular focus on material handling; and
- Validate the ability of the shredders to process pallets and, separately, plastics (DPE suits) and butyl rubber.

Several commercial shredders were used to size-reduce the solid materials of interest. A low-speed shredder was used to break up wooden pallets. The rough-shredded wood was size-reduced to small chunks in a hammer mill and then further reduced in a micronizer to the consistency of flour. Belt conveyors were used to transport feeds between the units. A bag house was used to collect dust generated by the shredding equipment. DPE suits with metal parts removed and butyl rubber (the material of boots and gloves) were rough-shredded in the low-speed shredder, cryocooled in a bath of LN<sub>2</sub>, and size-reduced in a granulator. The size-reduced wood, plastic, and rubber, along with activated carbon (air filter material) and energetics hydrolysate, were combined to produce a pumpable slurry to feed to the SCWO. The demonstration shredding equipment is identical in size to the units proposed for the full-scale system.

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<sup>18</sup> DPE suits are made of a plastic material containing chlorinated hydrocarbons.

Significant deviations from the planned demonstration testing included the following:

- Metal pieces were removed from DPE suits prior to shredding because removal by magnets after shredding was ineffective, resulting in damaged granulator blades.
- DPE suit plastic was successfully shredded to less than 0.12 in. (3 mm), a test objective, but this size proved to be too large to be fed to the demonstration SCWO unit without plugging the feed system. Alternatives for further size reduction were explored, but ultimately the plastic was sieved to 0.04 in. (1 mm) or less for use as feed for the SCWO dunnage validation runs.
- The hydropulper operation was not validated. Systemization and the single work-up run indicated that the unit provided no size-reduction benefit. The hydropulper may not be used in the final system design.

#### **5.2.1.3.4 Energetics Rotary Hydrolyzer**

The ERH was demonstrated to determine its effects on the physical and chemical properties of the munitions and liquid effluent. The objectives of the demonstration testing included the following:

- Demonstrate effective dissolution of aluminum and energetics in fuzes and bursters and propellant in rocket motors to allow downstream processing in the continuously stirred tank reactor (CSTR), SCWO, and HDC;
- Determine the extent of deactivation of the energetics in fuzes and bursters and the propellant in rocket motors;
- Validate the retention times for aluminum and energetics in fuzes and bursters and propellant in rocket motors; and
- Characterize the gas, liquid, and solid process streams from the ERH.

Fuzes, bursters, and rocket motor propellant were tested with the ERH, thereby demonstrating aluminum and energetics dissolution and energetics hydrolysis for a full-scale ERH. The ERH demonstration unit was a custom-designed cylindrical drum, 4 ft (1.2 m) in diameter ( $\frac{1}{2}$  of full scale) and 2 ft (0.61 m) wide filled with 8- to 12-molar NaOH, which rotated at the very slow rate of 0.1 rpm. The drum was heated with condensing steam at 212 to 230°F (100 to 110°C) to melt out the energetics and to increase the hydrolysis reaction rate. In the ERH tests, munition pieces were placed into the caustic-filled drum, and rotation was initiated for

periods up to 10 hours. Lifting flights in the drum were tilted at an angle to ensure that the energetics rolled off the flight as the flight rotated out of the NaOH solution, thus minimizing the time the energetics were out of solution. Aluminum metal dissolved to form aluminum salts and hydrogen, and the energetics dissolved and reacted with the NaOH to form an energetics hydrolysate.

There were no significant deviations from the planned demonstration testing.

#### **5.2.1.3.5 SCWO – Agent Hydrolysate**

SCWO was demonstrated to validate destruction of Schedule 2 and other organic compounds from agent hydrolysis products. Destruction of Schedule 2 compounds is a CWC requirement, and thus demonstration of the SCWO technology was essential. Testing had previously been performed with VX/NaOH hydrolysate during the ATP but had not been performed with HD or GB/NaOH hydrolysates. The objectives of the demonstration testing included the following:

- Validate the ability of the solid-wall SCWO to eliminate the Schedule 2 compounds present in the agent hydrolysate feeds;
- Validate the ability of the agent hydrolysis process and the SCWO to achieve a destruction removal efficiency (DRE) of 99.9999% for HD, GB, and VX;
- Demonstrate the long-term operability of the SCWO reactor with respect to salt plugging and corrosion; and
- Characterize the gas, liquid, and solid process streams from the SCWO.

For the SCWO agent hydrolysate tests, mixtures of agent hydrolysate, water, and/or auxiliary fuel, along with air, were fed to the SCWO reactor—a tubular continuous flow reactor operated at approximately 3,400 psia (23 MPa) and 705°F (374°C). In solid-wall SCWO, the injected feed mixture is rapidly heated to supercritical conditions and oxidized to CO<sub>2</sub>, water, and inorganic salts. Quench water is injected at the bottom of the reactor to cool the effluent and to dissolve the salts that are insoluble above the critical point of water. The effluent is further cooled in water-cooled heat exchangers and passed through a liquid/gas separator and pressure letdown system. Gaseous effluents are scrubbed in carbon filters and released to the atmosphere. During the demonstration testing, liquid effluents containing soluble and insoluble salts and metal oxides were collected and analyzed. The demonstrated SCWO system operated with a hydrolysate feed rate of approximately 0.1 gal/min (0.38 L/min), which is 1/10 to 1/20 the throughput cited for the full-scale unit.



Significant deviations from the planned demonstration testing included the following:

- SCWO treatment of VX hydrolysate was not demonstrated because of schedule constraints, and
- The proposed platinum-lined reactor was not used because of difficulties in fabrication.

#### **5.2.1.3.6 SCWO – Energetics/Dunnage Hydrolysate**

SCWO was demonstrated to validate destruction of organic compounds from energetic hydrolysis products and to show the feasibility of destroying organics in shredded solids. Characterization of gaseous, liquid, and solid effluents and verification of operating parameters were required.

The objectives of the demonstration testing included the following:

- Validate the ability of the ERH, CSTR, and SCWO to achieve a DRE of 99.999% for tetrytol, Composition B, and M28 propellant;
- Determine the impact of the aluminum from the ERH process on SCWO operation;
- Determine the extent to which the organics in the shredded dunnage are oxidized in the SCWO; and
- Characterize the gas, liquid, and solid process streams from the SCWO.

Energetics hydrolysate and shredded/slurried dunnage (wood, DPE material, butyl rubber, and fresh granulated carbon) were blended and processed through SCWO. In this test, organic products, water, and/or auxiliary fuel, along with air, were fed to a solid-wall SCWO reactor operated at approximately 3,400 psia (23 MPa) and 705°F (374°C). Because of the low heating value of the slurry, electric preheaters were used to heat the slurry prior to injection. In SCWO, the injected feed mixture is rapidly heated under supercritical conditions and oxidized to CO<sub>2</sub>, water, and inorganic salts. Quench water is injected at the bottom of the reactor to cool the effluent and to dissolve the salts that are insoluble above the critical point of water. The effluent is further cooled in water-cooled heat exchangers and passed through a liquid/gas separator and pressure letdown system. Gaseous effluents are scrubbed and passed through carbon filters and released to the atmosphere. During demonstration testing, liquid effluents containing soluble and insoluble salts and metal oxides were collected and analyzed. The demonstrated SCWO system

operated with a feed rate of up to 0.1 gal/min (0.38 L/min), which is 1/10 to 1/20 the throughput cited for the full-scale unit.

Significant deviations from the planned demonstration testing included the following:

- The proposed platinum-lined reactor was not used because of difficulties in fabrication.
- During some of the SCWO testing, energetics hydrolysates and slurried dunnage were treated in separate runs because of differing effects of feed pre-heating. During the last week of demonstration testing, however, three validation runs were conducted using a mixed feed of tetrytol hydrolysate and slurried dunnage.
- Aluminum hydroxide  $[\text{Al}(\text{OH})_3]$  was either removed from, or not added to, energetics hydrolysates prior to solid-wall SCWO treatment. Reactor plugging occurred while processing energetics hydrolysate feeds containing  $\text{Al}(\text{OH})_3$  were processed.

#### **5.2.1.3.7 Summary of Demonstration Testing**

Cryofracture and baseline reverse assembly are well-developed technologies and, therefore, were not demonstrated. During demonstration testing, the government validated that caustic hydrolysis is effective for destroying agents and energetics. The agent hydrolysis process produces Schedule 2 compounds; however, the solid-wall SCWO effectively destroyed all Schedule 2 compounds. The SCWO process effectively treats agent hydrolysates (demonstrated for HD and GB only), energetic hydrolysates, and dunnage, thus producing an effluent of low concern and impact to human health and the environment. Three hydrolysis/SCWO critical unit operations were demonstrated. Salt-plugging and corrosion of the SCWO unit are problems that will require further examination. These problems were to be examined during the engineering design studies (see Section 5.2.1.4). The PMACWA reviews the quality of the data generated during demonstration testing in PMACWA (1999c).

On the basis of demonstration testing, a number of process revisions were proposed that are applicable to BGAD and the munitions stored there. Most of these minor revisions relate to the munitions access processes or dunnage treatment. These changes include the following (General Atomics 1999):

- Mortar bursters could not be sheared in the burster size reduction machine (BSRM). However, the tetryl fill in the bursters was found to melt out in the

ERH during the demonstration tests. Thus, it appeared that size reduction would not be necessary.

- A live-bottom hopper would be used to collect shredded wood discharged from the low-speed shredder. The hopper would have a screw feeder at the bottom to meter the wood into the hammer mill. This change would prevent overfeeding of the hammer mill and micronizer.
- A separate low-speed shredder and collection hopper would be used to shred and store DPE suits and butyl rubber material before feeding to the cryocooler and granulator. This change would allow wood and plastic/rubber materials to be processed independently.
- DPE metal parts would be manually removed in a glove box before the DPE material would be fed to the DSHS. The metal parts would be treated to a 5X condition in the induction-heated batch MPF.
- A colloid mill would be used to wet-grind spent activated carbon to ensure adequate size reduction. The carbon slurry would then be added to the slurried dunnage and hydrolyzed energetics for processing through the SCWO system.
- Hydrolyzed aluminum, as  $\text{Al}(\text{OH})_3$ , would be filtered from energetics hydrolysate before being fed to the solid-wall SCWO system. This filtering would prevent hard aluminum salt deposits from plugging the SCWO reactor. The filtered  $\text{Al}(\text{OH})_3$  would be dried and decontaminated to a 5X condition in the MPF.

#### 5.2.1.4 Engineering Design Studies<sup>19</sup>

Although demonstration testing for the Demo I and Demo II technologies has been completed, Engineering Design Studies (EDSs) are being implemented. The PMACWA determined that these studies were necessary in preparation for full-scale pilot design and permitting. While EDSs have been completed for the Demo I technologies, they have not been completed for the Demo II technologies. This TRD presents information on planned EDS studies only. EDS-I objectives were as follows:

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<sup>19</sup> This material describes EDSs for the technologies evaluated in the Demo I PMACWA program and was derived, in part, from PMACWA (1999a). EDSs for Demo I technologies are designated EDS-I. Because EDSs are intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

- Provide information for the full-scale facility with respect to total life-cycle cost, schedule, and safety;
- Support the EIS and permit application preparation under RCRA; and
- Support preparation of a RFP for a full-scale pilot plant facility.

PMACWA (2000a) gives an overview of the EDSs for neutralization/SCWO. Figures 5.5 and 5.6 provide overviews of the neutralization/SCWO process and show unit operations that were evaluated during EDSs for projectiles and mortars (Figure 5.5) and for the M55 rockets (Figure 5.6).

The following subsections summarize planned EDS-I activities.

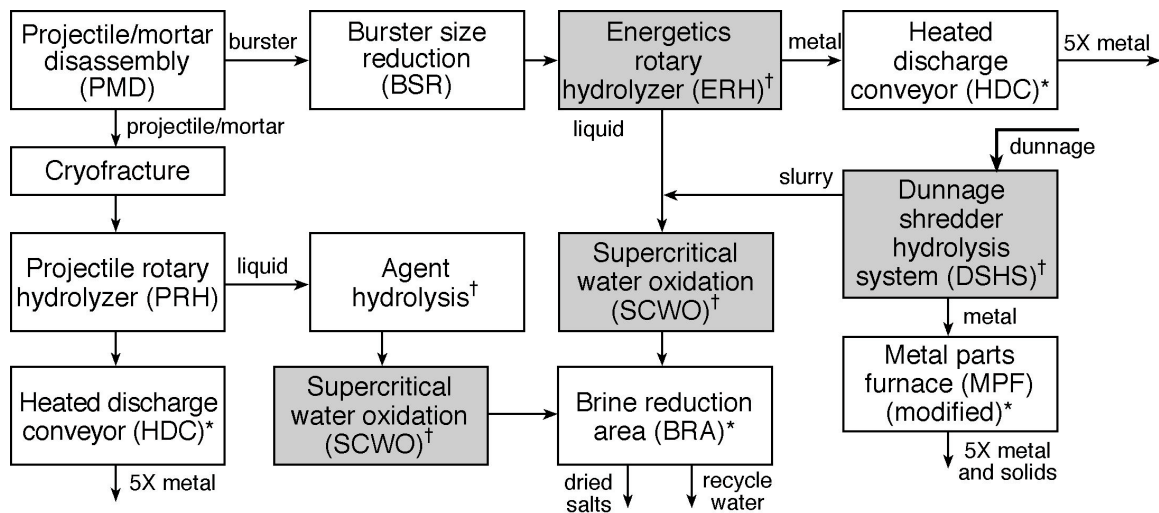
#### **5.2.1.4.1 Energetics Hydrolysis<sup>20</sup>**

Planned EDS activities for energetics hydrolysis consisted of the following:

- Addressing PMACWA and NRC (NRC 2000) concerns regarding particle size, solubility, by-products that would be produced as a function of time, control strategies, mixtures of energetics, and caustic concentrations; and
- Acquiring information for scale-up.

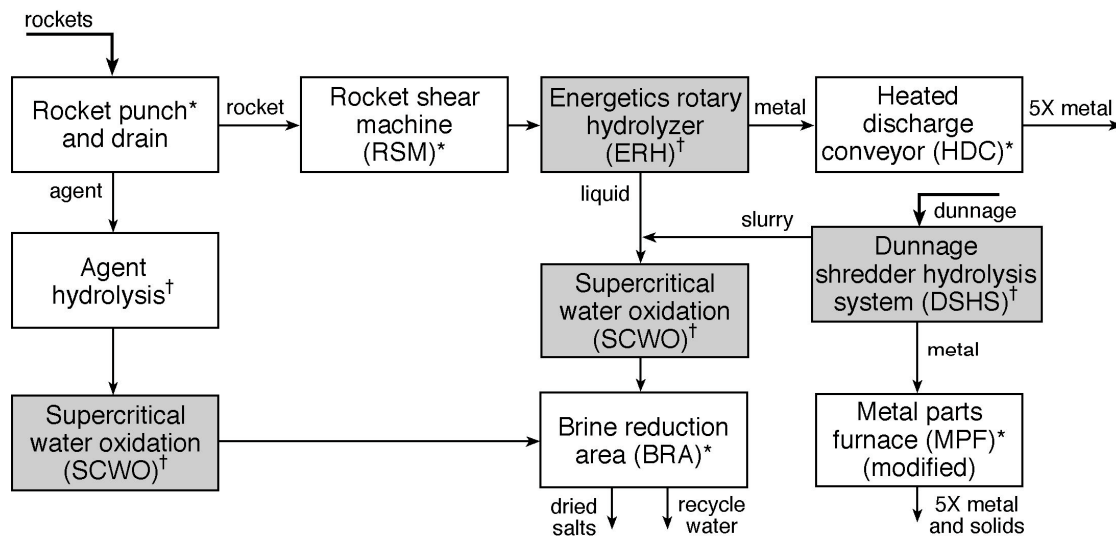
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<sup>20</sup> This is the same testing planned for neutralization/biotreatment and also is applicable to neutralization/GPCR/TW-SCWO.



BGAD05

**FIGURE 5.5 Flow Diagram of Neutralization/SCWO (General Atomics System) Showing Units or Operations Undergoing Engineering Design — Projectiles and Mortars (Source: Adapted from PMACWA 2000a)**



BGAD06

**FIGURE 5.6 Flow Diagram of Neutralization/SCWO (General Atomics System) Showing Units or Operations Undergoing Engineering Design — M55 Rockets (Source: Adapted from PMACWA 2000a)**

#### **5.2.1.4.2 Agent Hydrolysis<sup>21</sup>**

Planned EDS activities for agent hydrolysis consisted of the following:

- Determining the potential to use 15% by weight mustard agent hydrolysate for feed to the SCWO unit for increased throughput.

#### **5.2.1.4.3 Energetics Rotary Hydrolyzer**

Planned EDS activities for the ERH consisted of the following:

- Observing the effects of M28 propellant hydrolysis for rocket motor lengths less than 12 in. (30 cm) (i.e., 4 plus 8 in. [10 plus 20 cm]) and multiple pieces of rocket motor lengths (4 in. [10 cm]) and comparing them with results during demonstration (12 in. [20 cm]);
- Observing containment of fugitive emissions; and
- Observing the effect of a higher caustic concentration and bath temperature (19 M [50 wt%] NaOH, 277°F [136°C]; or highest allowable) on the rate of M28 propellant hydrolysis.

#### **5.2.1.4.4 Dunnage Shredder/Hydropulper System**

Planned EDS activities for the DSHS consisted of the following:

- Demonstrating changes to the dunnage shredding equipment for the full-scale design and verifying improved efficiency and uninterrupted operation (e.g., avoiding unit overloads), while still meeting original particle size requirements; and
- Generating information required for designing the duct emission control system.

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<sup>21</sup> This is the same testing planned for neutralization/biotreatment and also is applicable to neutralization/GPCR/TW-SCWO.

#### **5.2.1.4.5 Solid-Wall Supercritical Water Oxidation (HD and GB Hydrolysate Feed, Composition B/M28 Hydrolysate Feed, and Tetrytol Hydrolysate/Al(OH)<sub>3</sub>/Dunnage Feed)**

Planned EDS activities for solid-wall SCWO consisted of the following:

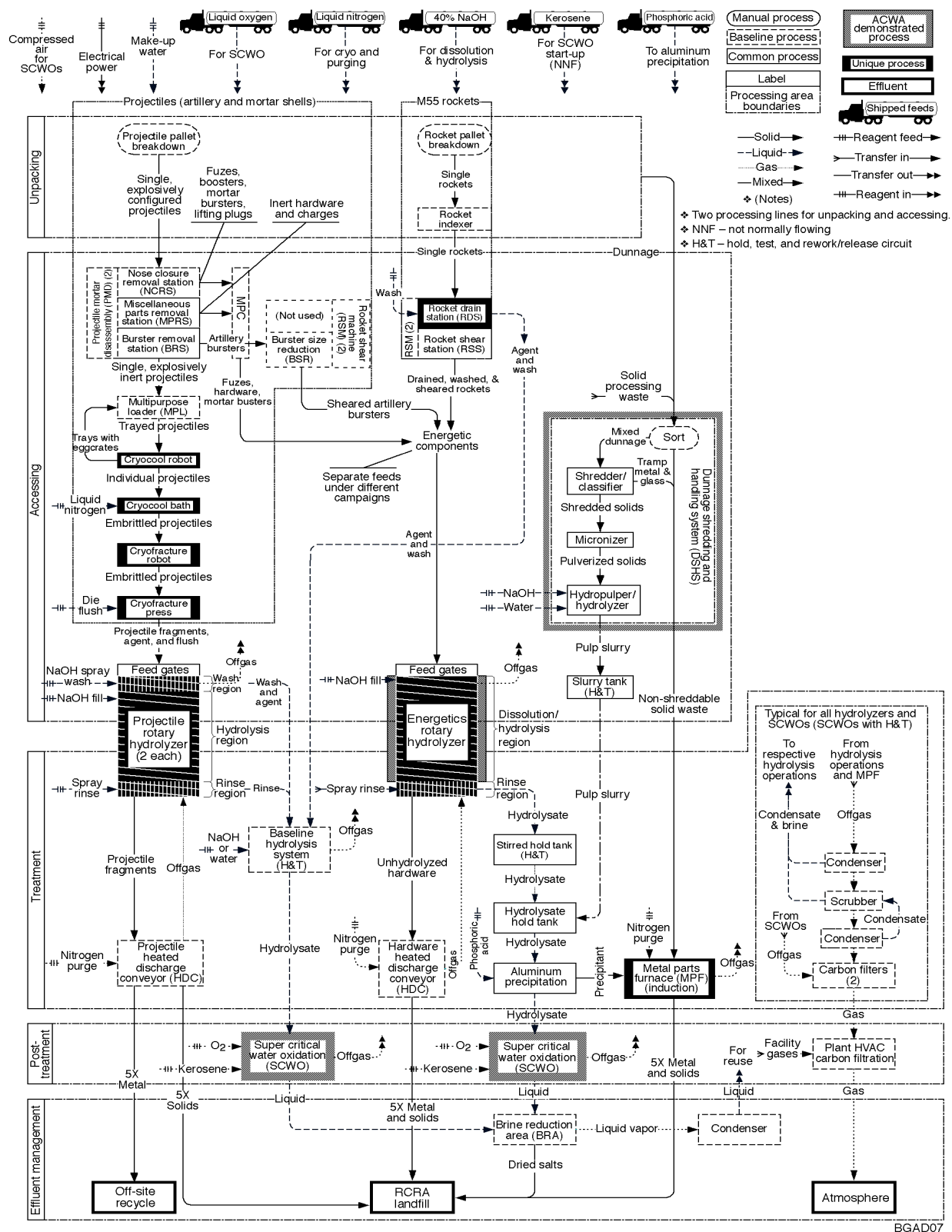
- Demonstrating long-term operability without plugging;
- Demonstrating an acceptable corrosion rate;
- Demonstrating that any feed additives for salt transport control do not interact with feed and/or equipment to generate salt plugs or accelerate corrosion;
- Determining a maintenance schedule and shutdown frequency on the basis of the results of long-term testing; and
- Generating data for use in validating the SCWO model development work sponsored by the U.S. Army Research Office.

As indicated previously, the results of EDSs for neutralization/SCWO were not included in this TRD.

#### **5.2.1.5 Detailed Process Description**

This section presents a detailed process description for neutralization/SCWO, as applied to BGAD and the ACW stored there, on the basis of demonstration testing results. The equipment used in a pilot-scale facility may vary in nomenclature and design from that described here, depending on the system selected and system requirements.

Figure 5.7 illustrates the entire process flow for the neutralization/SCWO process as applied to BGAD and the ACW stored there. As the figure shows, munitions access would involve use of a modified baseline reverse assembly and cryofracture for projectiles. For rockets, agent would be accessed first by using a punch and drain process. The rocket would then be sheared to access the fuze, burster, and propellant. Following munitions access, the process for treating specific agents and energetics would be largely independent of munition type and agent fill.



**FIGURE 5.7 Flow Diagram of Entire Neutralization/Solid-Wall SCWO Process at BGAD**  
(Source: Adapted from PMACWA 1999a,b)



Water hydrolysis followed by a caustic wash would be used for mustard agent, while caustic hydrolysis using NaOH would be used to neutralize nerve agent and energetics. Munition hardware would be treated with caustic in rotary hydrolyzers (rotating vessels with a helical transport flight<sup>22</sup>): the PRH would be used for agent-contaminated, cryofractured projectiles, and the ERH would be used for all other munition components.<sup>23</sup> Drained agents would be neutralized in CSTRs.<sup>24</sup> ERH effluent liquids would be treated in similar CSTRs. Dunnage and other organic solid wastes from projectiles and rockets would be shredded, pulverized, and water/caustic-pulped (with solids removal) into a slurry hydrolysate. Thermal treatment would be used to decontaminate solids not pulped. Solid effluents from the PRH and ERH would pass to modified (inert atmosphere) baseline HDCs for thermal decontamination to a 5X condition. Nonshreddable solid wastes (metals, glass, etc.) would receive thermal decontamination to a 5X condition in an induction-heated, inert atmosphere MPF. Munition bodies (projectiles) decontaminated to a 5X condition can be commercially recycled or disposed of as solid waste. Nonmetal solid waste, if defined as hazardous waste, would be managed as hazardous waste.<sup>25</sup> If defined as nonhazardous wastes, these solid wastes may be disposed of in a nonhazardous waste landfill.

Agent hydrolysate (independent of agent type), energetics hydrolysate from the ERH, and dunnage slurry hydrolysate would undergo secondary treatment in solid-wall SCWO units. The energetics hydrolysate and dunnage hydrolysate would be treated in a separate SCWO processing train. Brine from the SCWO units would be evaporated, the water would be condensed and recycled to the hydrolysis units, and the salts would be sent to a RCRA-permitted hazardous waste landfill.<sup>26</sup> The salts may need to be treated prior to placement in a landfill to meet RCRA land disposal requirements. Off-gases from the HDCs would vent to their respective rotary hydrolyzers. Off-gases from the hydrolyzers and the MPF would pass through condensers, scrubbers, and carbon filters before being released to the atmosphere. Liquid from condensers and scrubbers would return to the rotary hydrolyzers for reuse and eventual treatment by SCWO. SCWO off-gas would pass through carbon filters and be released to the atmosphere.

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<sup>22</sup> A continuous, flat plate (or “flight”) attached to the inner wall of the vessel, forming a corkscrew or augerlike apparatus from one end to the other. Material is moved along the bottom of the vessel by the helical transport as the vessel rotates.

<sup>23</sup> The terms PRH and ERH are specific to General Atomics. Conceptually, other processes that use a caustic washout design can be substituted for this process.

<sup>24</sup> CSTRs were developed pursuant to the U.S. Army’s ATP.

<sup>25</sup> Solids treated to remove residual agent may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste as defined in Title 40, Parts 260.21 – 260.24 of the *Code of Federal Regulations* (40 CFR 260.21 – 260.24).

<sup>26</sup> These salts may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste as defined in 40 CFR 260.21 – 260.24. Typically, these salts contain heavy metals and exhibit the RCRA toxicity characteristic (40 CFR 261.24). In Kentucky, the salts may be regulated as listed hazardous wastes because of their association with chemical agent. If the salts are listed as hazardous wastes, a RCRA delisting petition may be pursued to reclassify the waste as nonhazardous.

Short descriptions of each of the unit processes included in the neutralization/SCWO process as applied to projectiles and rockets stored at BGAD are provided below. Because of the differences in the munitions access process for projectiles versus rockets, a separate description of the munitions access process is provided. However, the remaining process descriptions (for agent and energetics treatment, dunnage treatment, metal parts treatment, and effluent management and pollution controls) apply to both projectiles and rockets. General Atomics (1999), which includes detailed process flow diagrams, may be reviewed for additional detail.

#### **5.2.1.5.1 Munitions Access – Projectiles**

The proposed design for munitions access for projectiles incorporates many of the units and processes used in the baseline reverse assembly processes (see Appendix E of Volume 1 for details). Units and processes include reverse assembly machines, material handling conveyors, robotic loaders and handlers, HDCs, elements of the MPF thermal treatment system, auxiliary systems, and facilities and support systems. Some of these units have been slightly modified from the baseline process, but the basic unit and operations have been retained. The major units are summarized below.

The projectile/mortar disassembly (PMD) machine and supporting equipment have been adopted without modification. The PMD is a custom-designed, automated machine that uses a turntable to position munitions at the various workstations that are arranged around the perimeter of the machine. Munitions would be processed in a horizontal position. Fuzes or lifting plugs, nose closures, supplementary charges, bursters, and other energetics would be removed. Bursters from projectiles would be conveyed to the BSRM. All removed hardware would be discharged through a chute to the floor of the explosion-containment room (ECR).

The BSRM and supporting equipment have been adapted from the baseline process. The BSRM is a modified rocket shear machine used to shear the mortar bursters and includes tooling kits for each burster size.

In the General Atomics system, the projectile/mortar cryofracture process would be used to access agent contained in the body of the projectiles. The process includes LN<sub>2</sub> baths and a hydraulic press capable of exerting a pressure of 500 tons (454 t). Two separate cryofracture treatment trains would be used. The press has a relatively small bed area and stroke, thereby reducing its size and weight. It fractures one munition body at a time. All of the tooling used in the baseline process would be adapted to the small press, including the same methods for mounting and fragment discharge. A tilt-table would be used to discharge fragments into a chute, which would deliver the fragments to the PRH. Decontamination/flush solution would also be supplied to the press tooling and discharge chute.

The cryocool bath is modeled after commercial food-freezing tunnels. A belt conveyor configured to handle a wide variety of munition types would transport munitions from the

loading station into the bath. The cryobath length would be sized to provide the residence time needed to ensure sufficient cryocooling of the munition and to support the required throughput rate for the production-scale system. The design of the conveyor and support fixtures would minimize ice and frost buildup. The unit would use baseline bridge robots to transport the munitions from the cryobath to the hydraulic press. Ventilation air would be vented through the ducts in the cryocool and press area, where it goes to the PRH.

#### **5.2.1.5.2 Munitions Access – Rockets**

The proposed design for the M55 rockets and the M56 rocket warheads incorporates the units and processes used in the baseline reverse assembly processes (see Appendix E of Volume 1 for details). Units and processes include reverse assembly machines, material handling conveyors, robotic loaders and handlers, elements of the MPF thermal treatment system, auxiliary systems, and facilities and support systems. Some of these units have been slightly modified from the baseline process, but the basic unit and operations have been retained.

The basic unit used for processing the rockets is referred to as the rocket shear machine (RSM). The RSM is a custom-designed, automated machine with both a punch and drain operation and a shear operation. Rockets would be clamped in the punch and drain station where the agent cavity would be punched, and the agent (GB or VX) would be drained. The drained agent would be pumped to a surge tank prior to hydrolysis. The rocket would then be indexed to the shear station where energetics would be accessed and size-reduced. One modification from the baseline process that has been instituted is to increase the size of the hole-punches, as well as the number of punches, to improve agent drainage and increase throughput. Further, a flush system has been added (using hot water) to wash out the agent cavity. Additional shear cuts would also be made to the rocket motor assembly to improve access to propellant.

#### **5.2.1.5.3 Agent Treatment**

Two PRHs would be used to treat agent from the projectiles. These units would be smaller than the ERH described below, but would be similar in design. The PRHs would receive cryofractured projectiles from the two cryofracture systems. The PRHs would operate in parallel; each would process about half of the projectile throughput. The PRHs would consist of large rotary drums with an internal helical flight as well as lifting flights. The helical flight would transport material along the axis of the drum and maintain batch separation. The lifting flights would ensure agitation and mixing of the hydrolyzing solution with the agent and metal parts. The drum would be steam-traced on the outside surface to maintain an internal operating temperature of about 212°F (100°C). At this temperature, agents would be readily hydrolyzed. A stationary shell of thermal insulation would enclose the drum and minimize heat loss. The materials would move through the hydrolyzer, where NaOH solution would be continually added at the feed end as agent and metal parts would be discharged by gravity into the drum along with flush solution. The helical flight would move a batch of hydrolyzing solution, agent, and metal

parts along the axis of the drum; each batch would contain several feeds of agent and metal parts. The drum would rotate slowly on drive rollers, and the batch would move such that residence time in the drum would be sufficient to ensure complete hydrolysis.

The drum would be supported at the discharge end by a spindle through which the coaxial steam supply and return lines pass. Axial loads would also be taken by the support trunion of the spindle. High-pressure sprays at the feed end of the drum would be used to melt and separate agent and agent heels from the metal parts. Most of the flushed agent and agent heel would flush through a perforated section of the drum at the feed end of the PRH into a tank, where agent hydrolysis would continue. Hydrolyzing solution would be added to the metal parts that travel through the drum beyond the perforated section. This hydrolyzing solution would travel through the drum, thereby decontaminating the metal parts, and would be discharged through a second perforated section at the discharge end of the drum. The hydrolysate would be transferred to a tank, where hydrolysis would be completed and verified.

Air would be pulled through the PRH to remove volatile organic compounds (VOCs) and other vapors. The air would then discharge to an air treatment system consisting of a scrubber, condenser, and carbon filters and would eventually be vented through the plant ventilation system.

The neutralization/SCWO system would incorporate the ATP neutralization system design being used at APG, with minor modifications to interface with other equipment. The neutralization system would be independent of the source of the agent (i.e., would process agent from projectiles and rockets) and would include six CSTRs and associated support systems. The hydrolysis process used for neutralization/SCWO would be chemically identical to that used for neutralization/biotreatment (see Section 5.2.2) and for neutralization/GPCR/TW-SCWO (see Section 5.2.3); however, the physical processes and equipment used would be different.

Secondary treatment of the agent hydrolysate to remove Schedule 2 compound would be accomplished using a solid-wall SCWO unit. The SCWO system for BGAD would be sized to process the hydrolyzed agent from the projectiles and rockets. The hydrolysate would first be collected in tanks that are sufficiently large to handle 10 hours of continuous operation. The SCWO system would employ a gas-fired preheater and auxiliary fuel system to heat the reactor to the desired operating temperature (705°F [374°C]), and the unit would be maintained at an operating pressure of 3,400 psia (23 MPa). Hydrolysate flow would be initiated, and auxiliary heat would be discontinued. Auxiliary fuel and preheat power would not be required under steady-state conditions.

The SCWO system for BGAD would be similar to that planned for NCD; however, the two SCWO units at BGAD would be slightly larger. The SCWO system would contain components needed to (1) accept and process hydrolysate piped from the hydrolysate holding tanks, (2) release brines to the BRA, and (3) release gaseous effluents to the plant ventilation system.

#### 5.2.1.5.4 Energetics Treatment

The ERH would be the main element for primary treatment of energetics. This unit would process energetics from projectiles and rockets in an identical manner. The design of the BGAD ERH is slightly larger than the design to be applied at PCD because of the larger throughput rate of energetics that is expected at BGAD (i.e., because of the M28 propellant contained in the M55 rockets).

The ERH would replace the baseline deactivation furnace system (DFS); however, it has been adapted to the same interfaces with other equipment as the DFS. The ERH is similar in design and operation to the PRH and receives energetics and metal parts containing energetics from the ECR. The ERH consists of a large rotary drum with an internal helical flight as well as lifting flights. The helical flight transports material along the axis of the drum and maintains batch separation. The lifting flights ensure agitation and mixing of the hydrolyzing solution with the energetics and metal parts. The drum is steam-traced on the outside surface to maintain an internal operating temperature of 212 to 230°F (100 to 110°C). At this temperature, energetics would be melted and the hydrolysis reaction would be enhanced. The materials would move through the hydrolyzer, where NaOH solution would continually be added at the feed end as energetics and metal parts are discharged by gravity into the drum, along with flush solution. The helical flight would move a batch of hydrolyzing solution, energetics, and metal parts along the axis of the drum; each batch would contain several feeds of energetics and metal parts. At the discharge end of the hydrolyzer, a perforated section of the drum would permit the hydrolysate to discharge into a CSTR to complete hydrolysis of any remaining small particles of energetics. The hydrolysate would subsequently be pumped to continuously stirred holding tanks. The hydrolysate would then discharge to the energetics hydrolysate/dunnage hydrolysate SCWO treatment system.

Air would be pulled through the ERH to remove hydrolysis vapors and fumes, including hydrogen produced from the hydrolysis of aluminum burster wells that make up some projectiles. Sufficient air flow would ensure that the hydrogen concentration remains well below the lower explosive limit (LEL) for hydrogen. The air would then discharge to an air treatment system consisting of a scrubber, condenser, and carbon filters and would eventually vent through the plant ventilation and carbon filter system.

Secondary treatment of the energetics hydrolysate and dunnage slurry (see Section 5.2.1.5.6) would be accomplished with a solid-wall SCWO unit identical in design and capacity to the agent hydrolysate SCWO system described above. The SCWO units employed would be similar in design to the SCWO units planned for pilot testing at NCD. The major difference would be in the slurry feed and the high-pressure pump system.

#### **5.2.1.5.5 Metal Parts Treatment**

The munition bodies (projectiles only) would discharge from the PRH to modified baseline HDCs. The metal parts from energetics treatment (including mostly rocket parts, but also metallic parts from energetic portions of projectiles) would continue along the axis of the perforated section of the ERH drum and discharge through a chute to a separate HDC. In both HDCs, metal parts would be heated to a minimum 1,000°F (538°C) for a minimum of 15 minutes. The metal parts would be treated to meet a 5X condition, thus destroying residual agent and energetics. Metal from the DSHS would be decontaminated to a 5X condition in the MPF.

#### **5.2.1.5.6 Dunnage Treatment**

Dunnage would be treated during the campaign to the extent possible. Material would be processed by shredding and slurring. The slurried dunnage would then be treated in the energetics hydrolysate/SCWO system. Although not all dunnage would be agent-contaminated, all dunnage would be treated on-site in this manner.

Nonmetallic dunnage materials — wood, paper, plastic, DPE suits, and spent carbon — would be size-reduced in a series of steps and fed to a commercial hydropulper and grinding pump that would slurry the material to a particle size of less than 0.04 in. (1 mm). Wood dunnage would be size-reduced in a dedicated low-speed shredder, hammer mill, and micronizer to achieve a fine particle size suitable for slurring. DPE suits and butyl rubber would be shredded in a dedicated low-speed shredder and then cryocooled and granulated to achieve adequate size reduction. Spent activated carbon would be wet-ground in a dedicated colloid mill. A dilute solution of NaOH would be added to decontaminate the size-reduced solids in the slurry. The resulting slurry would be expected to have a particle content of about 10% by weight. This slurry would then be blended with the energetics hydrolysate. At this point, additives would be used to ensure that the solids remain in suspension and that the slurry can be readily pumped and processed in the energetics SCWO system.

#### **5.2.1.5.7 Effluent Management and Pollution Controls**

The effluent management and pollution control systems used in neutralization/SCWO would be similar to systems used in the baseline incineration plant. These systems would be independent of agent and munition type. Elements of the system are described below.

The plant ventilation system is designed with cascading air flow from areas of less contamination potential to areas with more contamination potential. The ventilation system

permits room air-change frequencies consistent with area-level designations<sup>27</sup> for normal as well as anticipated maintenance activities. Plant ventilation flow would be collected in the main plenum and directed to a bank of carbon filters. From there, the air would be filtered and monitored, passed through induction draft fans, and exhausted to the stack and the atmosphere. This system would be nearly identical to the baseline system.

The decontamination fluid supply and spent decontamination fluid collection systems would be the same as those in the baseline system. Decontamination fluid would be supplied to most rooms in the main plant area, and spent decontamination fluid would be collected in sumps that would be monitored and controlled. The spent decontamination fluid would then be transferred to the spent decontamination system (SDS) treatment area, where it would be mixed with additional decontamination solution to ensure complete destruction of agent.

The DPE-supplied air and personnel support system would include maintenance air locks, donning/doffing support equipment, and facilities identical to the baseline system.

The BRA would be identical to that used in the baseline system except that it would be modified to handle brine salts from the SCWO process and water recovery by condensation for reuse in the plant. The BRA includes equipment for effluent drying in heated drums. If classified as hazardous waste, dried salts would be disposed of in a hazardous waste landfill.

The plant instrument air supply and steam supply systems would be identical to those employed in the baseline system.

Control rooms would be the same as those used in the baseline system, with changes as needed to accommodate the new systems and equipment.

The process for handling munitions from storage to the unpack area would be similar to that used for the baseline system.

Personnel support, monitoring systems, and analytical laboratories would be similar to those used in the baseline system.

As indicated previously, elements of the baseline incineration process are included in the overview of baseline and ACWA system technologies provided in Volume 1 of this TRD (see Section 1.4). In addition, the baseline incineration process is described in Appendix E of Volume 1.

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<sup>27</sup> Level A, B, C, D, or E indicates the potential for contamination; Level A is the highest, and E is the lowest.

### 5.2.1.6 Common Elements – Other Systems

The neutralization/SCWO process has several elements that are identical or nearly identical to other systems. Commonalities with other applicable technology systems include the following:

- The munitions access system used for neutralization/SCWO employs much of the baseline reverse assembly system, as do the other ACWA systems;
- Neutralization/SCWO, neutralization/biotreatment, and neutralization/GPCR/TW-SCWO employ neutralization as a primary treatment for chemical agents and energetics; and
- Neutralization/SCWO and neutralization/GPCR/TW-SCWO each employ SCWO systems. Although the solid wall and transpiring wall SCWO systems differ, they are interchangeable.

Facility structure; ventilation; decontamination fluid supply; personnel support; pollution abatement; water, air, and steam supply systems; control rooms; monitoring systems; and laboratory support would be identical or nearly identical to the baseline system.

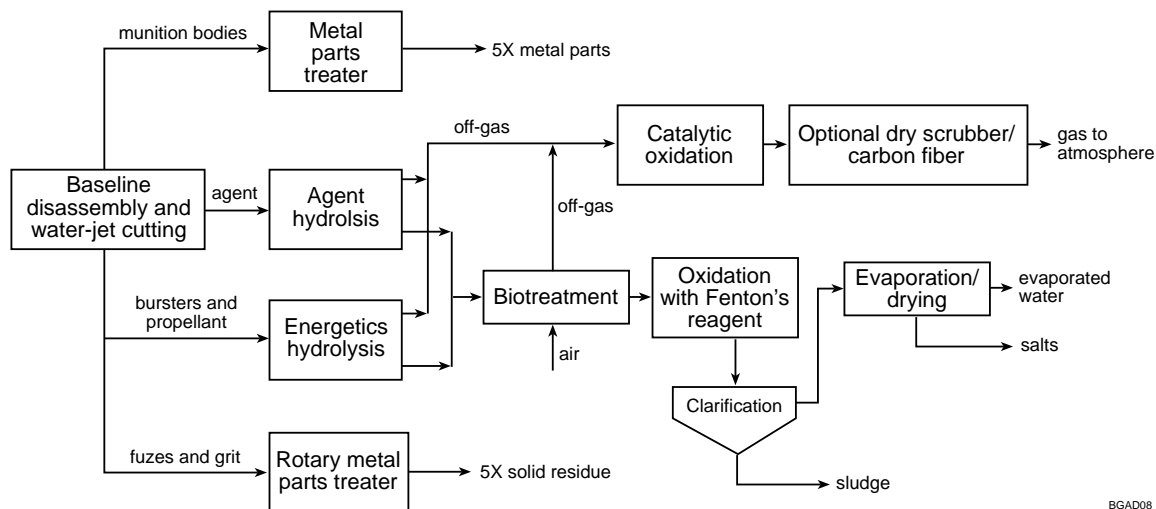
## 5.2.2 NEUTRALIZATION/BIOTREATMENT

The neutralization/biotreatment technology system consists of neutralization of agents and energetics and secondary treatment of neutralization residuals using biotreatment. This technology system, proposed by Parsons/Honeywell, is only fully applicable to ACW stored at BGAD that contain mustard agent. During demonstration testing, biotreatment of nerve agent residuals (i.e., hydrolysates) was unsuccessful. Therefore, the biotreatment process is not applicable to ACW at BGAD that contain nerve agent. However, nonbiotreatment elements of this technology system may be used in addition to or in place of elements of other technologies used in this system for those ACW at BGAD that contain nerve agent. The following subsections provide a more detailed discussion of the technologies and processes involved in this system. The technology provider's technology demonstration report (Parsons/Allied Signal 1999) may be viewed for additional detail.<sup>28</sup>

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<sup>28</sup> Honeywell purchased Allied Signal in early 2000; General Electric purchased Honeywell in 2000. Parsons/Honeywell refers to its ACWA system as the Water Hydrolysis of Explosives and Agent Technology (WHEAT) process.





**FIGURE 5.8 Overview of the Neutralization/Biotreatment Process (Parsons/Honeywell System) for the Treatment of ACW at BGAD (Source: Adapted from NRC 1999)**

### 5.2.2.1 Process Overview

Figure 5.8 shows the neutralization/biotreatment process as applied to projectiles at BGAD. A modified baseline reverse assembly process would be used to disassemble munitions. In the proposed Parsons/Honeywell system, modifications would include fluid-abrasive cutting of bursters, followed by fluid-mining of burster charges. The HD would be neutralized/hydrolyzed using water in units operated at 194°F (90°C) and atmospheric pressure; energetics would be neutralized/hydrolyzed by using a NaOH solution in units also operated at 194°F (90°C) and atmospheric pressure. Neutralization of mustard agent using water would be followed by a caustic wash using NaOH. Agent and energetic hydrolysates would be biotreated together in aerobic reactors called immobilized cell bioreactors (ICBs™) and supplementally treated with hydrogen peroxide/ferrous sulfate (H<sub>2</sub>O<sub>2</sub>/FeSO<sub>4</sub> [Fenton's reagent]). Metal parts and dunnage would be decontaminated to a 5X condition in an electrically heated steam furnace. Gaseous discharges would be catalytically converted by using a catalytic oxidation (CatOx) system to remove trace organics, oxidizable nitrogen, and chlorine compounds (NRC 1999) before being discharged to the atmosphere. Emissions from the CatOx system do not require high-efficiency particulate air (HEPA) or carbon filtration (Parsons/Allied Signal 1999).<sup>29</sup>

<sup>29</sup> The terms ICB and CatOx are specific to Parsons/Honeywell. Conceptually, other processes using similar techniques could be employed.

### **5.2.2.2 History of Destructive Processes**

Neutralization and biotreatment are the primary destructive processes employed in this technology. The histories of these processes are summarized below.

#### **5.2.2.2.1 Neutralization of Agent and Energetics**

Agent and energetics neutralization by hydrolysis were reviewed in Section 5.2.1.2.1. Since the history of neutralization of agent and energetics for neutralization/SCWO does not differ from the history of neutralization of agent and energetics for neutralization/biotreatment, this information is not repeated.

#### **5.2.2.2.2 Biological Treatment**

Different forms of biotreatment have been employed for many years to treat various types of domestic and industrial wastes. Most notable are sewage treatment plants, which are used to reduce the organic, nutrient, and pathogenic content of domestic sewage. Biotreatment is a well-developed, mature, and accepted technology for the treatment of a wide variety of waste types.

Theoretically, microorganisms can degrade almost any organic compound to basic elements (NRC 1999). The use of a biotreatment system is dependent on maintaining a proper environment in which microbes can readily degrade organic contaminants to desired levels. A proper balance of organic food sources and nutrients must be available to the microorganisms (NRC 1999). Other conditions, such as pH, temperature, and oxygen levels, must be carefully maintained. In practice, however, the toxicity of organic and inorganic components in the feed to a biotreatment process can be a limiting factor and requires careful monitoring and control (NRC 1999).

Biotreatment of HD hydrolysates will be pilot tested at APG for the bulk HD stored there. The U.S. Army prepared an EIS for the hydrolysis/biotreatment process proposed for APG (PMCD 1998a). The process involves hydrolysis using a water/caustic solution, followed by biotreatment, and a final polishing step in the facility wastewater treatment plant. The U.S. Army concluded in its EIS that the proposed APG facility would meet stringent permitting requirements of the CWA, RCRA, CAA, and associated State of Maryland regulations. The U.S. Army further concluded that the site and environs of the facility would be affected by construction and pilot testing of the proposed facility, but that appreciable adverse human health and environmental impacts would be well within regulatory limits (PMCD 1998a).

### 5.2.2.3 Demonstration Testing<sup>30</sup>

The neutralization/biotreatment technology was demonstrated during Demo I of the PMACWA demonstration test program. Demo I testing was conducted in spring 1999. This section provides a summary of demonstration testing for neutralization/biotreatment. Demo I testing results are provided in PMACWA (1999a).

Baseline reverse assembly, carbon filtration, the BRA operations, and other technologies common to baseline operations were not evaluated during ACWA demonstration testing of neutralization/biotreatment. In addition, the following unit operations proposed for neutralization/biotreatment were not selected by the PMACWA for demonstration for the reasons given below.

Continuous Steam Treater (CST). This is a new addition to the proposed full-scale process that was incorporated after demonstration was conducted. It is described as a rotary version of the metal parts treater (MPT).

Dunnage Processing (noncontaminated). The originally proposed noncontaminated dunnage processes (shredding, neutralization, and biotreatment) were not considered pertinent to ACWA mixed munitions demilitarization.

The rationales for selecting the neutralization/biotreatment demonstration unit operations, testing objectives, and significant deviations from the planned testing are described in the following subsections.

#### 5.2.2.3.1 Agent Hydrolysis

The U.S. Army previously demonstrated agent hydrolysis extensively in its ATP. The PMACWA ran agent hydrolysis units primarily to provide representative feedstock for biotreatment and to characterize the intermediate product stream for residual agent, Schedule 2 compounds, and other substances required to verify the mass balance. The specific test objectives of these demonstration units were identical to those for neutralization/SCWO and included the following:

- Design, fabricate, and deliver GB and VX hydrolysate production systems with the production capacity of 100 gal (379 L) of hydrolysate per run;

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<sup>30</sup> This material was derived from PMACWA (1999a) and refers to demonstration testing during Phase I of the ACWA demonstration process. Because demonstration testing was intended to apply to all ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

- Use the hydrolysate recipes developed and tested by the ECBC;
- Demonstrate that the agent concentration in the hydrolysate solution is less than the waste control limit by using the analytical methods developed and approved by the ECBC;
- Characterize solid, liquid, and gas process streams; and
- Provide agent hydrolysate in support of demonstration testing.

GB and VX hydrolysate were produced in a newly constructed 100-gal (379-L) stirred tank reactor at CAMDS. The design and manufacture of a hydrolysis system provided information on equipment and operational parameters that can be used for scale-up to a full-scale facility. VX hydrolysate and GB hydrolysate were produced for use in the ICB units at CAMDS.

HD hydrolysate was produced at the CTF at APG. The equipment used was not intended to be a model for scale-up to a full-scale facility, but was an expedient design suitable for use in the contained environment of the CTF. HD hydrolysate was produced for use in the ICB unit at the ECBC.

There were no significant deviations from the planned demonstration testing.

#### **5.2.2.3.2 Energetics Hydrolysis**

Other government agencies have previously evaluated energetics hydrolysis; however, further knowledge of the process was needed for evaluation, feedstock for biotreatment was required, and the characterization of the intermediate product streams for residual energetics and other substances was required to verify the mass balance. The specific test objectives of these demonstration units were identical to those for neutralization/SCWO and included the following:

- Produce energetics hydrolysate for use as feed in subsequent demonstration testing;
- Characterize solid, liquid, and gas process streams; and
- Gather process operation information to support the ACWA program and future scale-up.

M28 propellant was hydrolyzed with 6% NaOH to produce hydrolysate in one production run at the Radford Army Ammunition Plant, Radford, Virginia. Composition B and 63 lb (29 kg)

of tetrytol were hydrolyzed using 6% NaOH at the Pantex Plant, Amarillo, Texas, and were used as feedstock for the ICBs.

There were no significant deviations from the planned demonstration testing.

#### **5.2.2.3.3 Rocket-Cutting and Fluid-Mining**

Fluid-abrasive cutting and fluid-mining are reasonably well-established industrial operations; however, the ability to cut through the materials in an M55 rocket was not the primary reason for demonstrating these operations. Rather, one reason for demonstrating these operations was to verify their application to accessing energetics in the ACW components. Another reason concerned adaptation of fluid-abrasive cutting to the baseline reverse assembly equipment. Fabrication of robotics for automating fluid-abrasive cutting was not viewed as a requirement; demonstrating the effectiveness of the system to access, extract, and wash out energetics, however, was required. In addition, characterization of the quantity and type of grit required, fluids produced, energetics remaining in the rocket, and the size distribution of energetic particles from rocket access and washout was considered important.

The rocket-cutting and fluid-mining unit operation was designed to demonstrate the fluid-abrasive cutting and fluid-mining of M55 rocket energetic components. The objectives of this demonstration unit included the following<sup>31</sup>:

- Demonstrate the ability to perform circumferential cuts of a rocket at required locations along the rocket length;
- Demonstrate effective fluid-mining and separate collection of rocket bursters, motor propellants, and residual agent simulant;
- Demonstrate the ability to maintain control of rocket metal and plastic parts from cutting and fluid-mining operations;
- Determine energetic particle size of fluid-mined rocket bursters and propellant; and
- Determine the requirements for separating used grit from the residual cutting solution.

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<sup>31</sup> These objectives are potentially applicable to other ACW at BGAD.

The demonstration tests were conducted with ten 115-mm inert M60 rockets filled with concrete and plaster of paris, and ten M61 rockets, which are identical to the M55 rockets but filled with ethylene glycol rather than agent. The demonstration unit applied fluid-abrasive cutting to remove the fuzes and cut the rocket casing, fluid-mining to wash out the burster energetics, and fluid-mining to remove the propellant. However, fluid-mining to remove the propellant was terminated prior to the start of validation testing.

Several aspects of the proposed fluid-abrasive, fluid-mining, or washout operations that the PMACWA had considered demonstrating were not included in the final demonstration testing matrix: fuze washout, fluid-abrasive cutting of mortars, and use of the process effluents for subsequent unit feeds. These items were determined to be unnecessary for a successful demonstration. Energetics in these items are expected to melt out in the MPT or CST.

#### **5.2.2.3.4 Immobilized Cell Bioreactor and Catalytic Oxidation**

Allied Signal established the ICB as a commercial treatment for industrial wastewater. Thus, a primary reason for demonstrating the ICB was to validate it with the hydrolysates generated from neutralization of agent.

The PMACWA determined that it was necessary to conduct separate ICB demonstrations because the HD/tetrytol hydrolysate ICB is designed differently than the ICBs for VX/Composition B/M28 propellant hydrolysate and GB/Composition B hydrolysate, and because the products of each of these hydrolysates represented unique challenges to biotreatment technology. Furthermore, the ICB requires several weeks to acclimate, and validation testing requires approximately 40 days. As a result, it was effectively impossible to run two separate validation tests with a single ICB within the period available for the ACWA demonstration.

In addition to the primary operation of the ICB, the demonstration also included water recycling to verify the effectiveness of the Fenton's reagent ( $\text{H}_2\text{O}_2/\text{FeSO}_4$ ) on each specific feed, both for destruction of the compounds of concern and for its impact on water recycling. This also allowed the demonstration unit to provide a detailed characterization of what remains in solid biomass (which is required for destruction) and what constituents return with the recycled water. In addition, three CatOx units were included as part of the ICB unit operation (one for each ICB). The CatOx units were included to validate their performance with the ICB gaseous effluent and to allow a detailed characterization of product gases for final treatment.

The ICBs were designed to demonstrate the ability to biotreat the agent and energetic hydrolysates. The objectives of these demonstration units included the following:

- Validate the ability of the unit operations to eliminate Schedule 2 compounds present in the hydrolysate feeds;

- Confirm the absence of agent in the unit operation effluents;
- Validate the ability of the agent hydrolysis processes, the ICB, flocculation reactor, and clarifier unit operations to achieve a DRE of 99.9999% for agent;
- Validate the ability of the energetic hydrolysis processes, the ICB, flocculation reactor, and clarifier unit operations to achieve a DRE of 99.999% for energetics;
- Develop mass loading and kinetic data that can be used for scale-up of the ICB, flocculation reactor, and clarifier unit operations;
- Validate the ability of the CatOx to eliminate organic compounds, and Schedule 2 compounds specified in the Demonstration Study Plan from the ICB process gas streams;
- Determine the potential impact of operating conditions on the fouling and plugging of the CatOx; and
- Characterize the gas, liquid, and solid waste streams from the unit operations for the constituents specified in the Demonstration Study Plan.

The PMACWA conducted three separate ICB demonstrations, one for each of the following combinations of agent and energetic hydrolysates (PMACWA 1999a):

- HD hydrolysate and tetrytol hydrolysate to simulate the material contained in the M60 105-mm projectile;
- VX hydrolysate, Composition B hydrolysate, and M28 propellant hydrolysate to simulate the material contained in the M55 rocket; and
- GB hydrolysate and Composition B hydrolysate to simulate the material contained in the M426 8-in. projectile.

Each ICB demonstration unit consisted of the ICB plus an associated flocculation reactor, clarifier, and CatOx unit.

Certain aspects of the ICB operations were considered for demonstration but were not included in the final demonstration test matrix. These included determining the sensitivity of the ICB to expected impurities, such as MPT liquid effluents, and demonstrating sludge dewatering

and brine reduction operations. These items were determined unnecessary for a successful demonstration.

#### **5.2.2.3.5 Metal Parts Treater and Catalytic Oxidation**

The MPT is a thermal treatment unit that decontaminates metal parts and dunnage to a 5X condition by maintaining the temperature above 1,000°F (539°C) for the required time (minimum of 15 minutes). The ability of the MPT to effectively treat metal parts to a 5X condition was not a primary reason for demonstrating the unit; it was demonstrated because of several issues raised during the initial evaluation. These issues included the ability to treat dunnage, the ability to control agent driven from metal parts, and the need to characterize products for all process streams.

Because of the lack of information on the effluents from the MPT, it was considered important to test the unit with as many varied feeds as possible. Therefore, the MPT was demonstrated using mortar bodies containing a quantity of agent representing a 10% heel of GB, VX, and HD. This was considered a worst-case scenario on the basis of the original approach of washing out the projectiles. The MPT was also tested with carbon, pentachlorophenol (PCP)-contaminated wood, fiberglass from rocket shipping and firing tubes, and DPE suit material.

Part of the gaseous effluent treatment for the MPT includes another CatOx unit followed by carbon filters. The most important reason for conducting this demonstration was to characterize the effluents from the MPT. The CatOx demonstration was also considered important because this unit has the potential to extend the life of carbon filters in a variety of demilitarization applications. If the MPT were to produce agent or Schedule 2 compounds in the gas phase, the CatOx could treat them; validation of this capability was a reason for the demonstration. A direct challenge of undiluted agent was considered the ultimate test of this unit; therefore, HD, VX, and GB were all directly fed into the unit to determine the ability of the CatOx unit to destroy any agent volatilized in the MPT.

The MPT unit operation was designed to demonstrate the MPT, its associated condensate recovery system (CRS), and the attached CatOx. The objectives of these demonstration units included the following:

- Validate the ability of the MPT process to treat dunnage,
- Determine what pyrolysis products are produced in the MPT during processing of dunnage and their impact on the downstream condenser,
- Characterize the liquid effluent from the MPT condenser to determine its suitability for processing in the agent hydrolysis reactor,



- Validate the ability of the MPT condenser and the CatOx to eliminate chemical agents and Schedule 2 compounds from the process gas stream,
- Determine the potential impact of operating conditions on the fouling and plugging of the CatOx, and
- Characterize the gas, liquid, and solid waste streams from the MPT for the constituents and properties specified in the Demonstration Study Plan.

The MPT unit operation was tested with the following:

- M2A1 mortar body with a 10% liquid agent heel,
- Wood pallet material spiked with 0.4% PCP,
- Carbon,
- Fiberglass shipping and firing containers, and
- Double-bagged DPE suits with boots and gloves.

In addition, the CatOx portion of the unit was tested with direct GB, VX, and HD vapor feed.

There were no significant deviations from the planned demonstration testing.

#### **5.2.2.3.6 Summary of Demonstration Testing**

The neutralization/biotreatment system for fluid-abrasive cutting and fluid-mining was, for the most part, demonstrated during the demonstration test phase. M28 propellant, however, present only in M55 rockets, could not be adequately removed from munition items using fluid-mining. An alternative proposal is to push or pull the M28 propellant grain out of the rocket motor casing. The grain would then be sheared and shredded to produce a slurry. The destruction of agents and energetics using hydrolysis was validated in government testing. Use of hydrolysis, along with the thermal treatment of metal parts and other solid wastes, has been validated to effectively treat mustard and nerve agents and the energetic components of ACW. The agent hydrolysis process does, however, produce CWC Schedule 2 compounds. For mustard-agent type munitions, these Schedule 2 compounds were effectively treated in the ICB unit. The process of neutralization followed by biotreatment for the demilitarization of ACW containing mustard agent was validated during demonstration. Therefore, this process is considered a viable

total solution for the demilitarization of ACW containing mustard agent. The process of neutralization followed by biotreatment for the demilitarization of ACW with nerve agent was not validated during demonstration. Therefore, without further development, this process is not considered a viable total solution for the destruction of ACW with nerve agents. The PMACWA reviews the quality of the data generated during demonstration testing in PMACWA (1999d).

On the basis of demonstration testing, Parsons/Honeywell indicated that a number of subsequent studies would be needed to optimize system components and to integrate them with baseline components that are included in the total system (Parsons/Allied Signal 1999). However, no significant changes were proposed to the neutralization/biotreatment system as a result of demonstration testing.

#### 5.2.2.4 Engineering Design Studies<sup>32</sup>

Although demonstration testing for the Demo I and Demo II technologies has been completed, EDSs are being implemented. The PMACWA determined that these studies were necessary in preparation for full-scale pilot design and permitting under RCRA. While EDSs have been completed for the Demo I technologies, they have not been completed for the Demo II technologies. This TRD presents information on planned EDS studies only. EDS-I objectives were as follows:

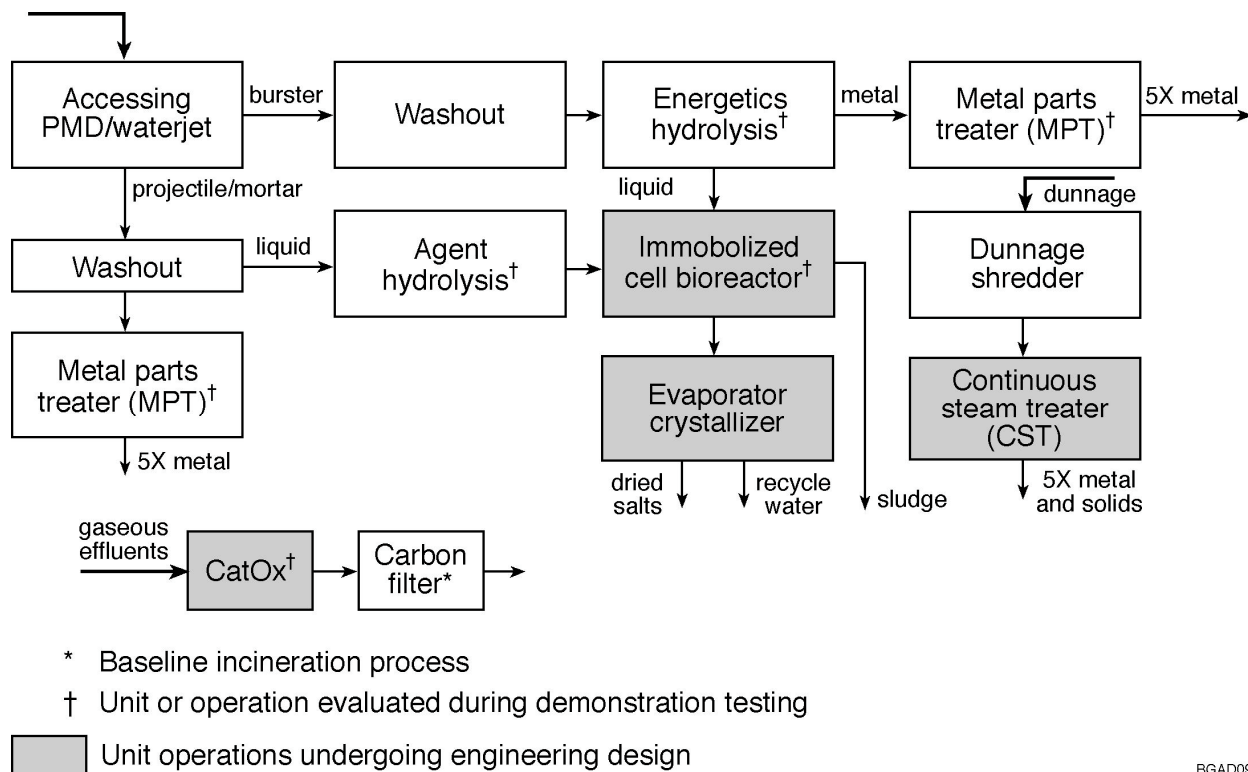
- Provide information for the full-scale facility with respect to total life-cycle cost, schedule, and safety;
- Support the EIS and RCRA permit application preparation; and
- Support preparation of a RFP for a full-scale pilot plant facility.

PMACWA (2000a) gives an overview of the EDSs for neutralization/biotreatment. Figure 5.9 provides an overview of the neutralization/biotreatment process and shows unit operations that were evaluated during EDSs for projectiles. It is unclear whether carbon filtration would be employed in the final pilot-scale design. For demonstration and EDS testing, the carbon filter was employed as a safeguard because of uncertainty regarding performance of the CatOx system.

The following subsections discuss the EDS activities that were planned.

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<sup>32</sup> Because EDSs were intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.



BGAD09

**FIGURE 5.9 Flow Diagram of Neutralization/Biotreatment (Parsons/Honeywell System) Showing Units or Operations Undergoing Engineering Design — Projectiles (Source: Adapted from PMACWA 2000a)**

#### 5.2.2.4.1 Energetics Hydrolysis<sup>33</sup>

Planned EDS activities for energetics hydrolysis consisted of the following:

- Addressing PMACWA and NRC (NRC 2000) concerns regarding particle size, solubility, by-products that would be produced as a function of time, control strategies, mixtures of energetics, and caustic concentrations; and
- Acquiring information for scale-up.

<sup>33</sup> This is the same testing planned for neutralization/SCWO and also is applicable to neutralization/ GPCR/TW-SCWO.

#### 5.2.2.4.2 Agent Hydrolysis<sup>34</sup>

Planned EDS activities for agent hydrolysis consisted of the following:

- Determining the potential to use 15% by weight mustard agent hydrolysate for feed to the ICB unit for increased throughput.

#### 5.2.2.4.3 Immobilized Cell Bioreactor and Catalytic Oxidation

Planned EDS activities for the ICB and CatOx consisted of the following:

- Observing the long-term (4 months and 4 biomass retention times) continuous operation of the ICB unit, exclusive of unanticipated extended downtime, under proposed full-scale operating conditions (e.g., aeration, effluent recycling, and original planned HD hydrolysate feed rate);
- Observing the ability of secondary unit operations (e.g., clarifier, filter press, and evaporator/crystallizer/filter press) to operate as proposed;
- Confirming critical design parameters (e.g., aeration rate, CatOx loading) developed during demonstration testing;
- Observing effective control of the biomass throughout the ICB process, including growth within the ICB unit and separation within the clarifier and filtration;
- Observing the effectiveness of the proposed full-scale control strategy for the ICB, clarifier, CatOx, and evaporator/crystallizer/filter press;
- Characterizing the CatOx outlet, crystallizer off-gas, biomass, and brine salts from the ICB process for selected chemical constituents and physical parameters, and the presence or absence of hazardous, toxic, agent and Schedule 2 compounds; and
- Observing the ability of the ICB unit to treat the neutralized CST condensate as part of the feed stream to the ICB.

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<sup>34</sup> This is the same testing (planned) for neutralization/SCWO and also is applicable to neutralization/GPCR/TW-SCWO.

#### **5.2.2.4.4 Continuous Steam Treater and Catalytic Oxidation**

Planned EDS activities for the CST and CatOx consisted of the following:

- Observing the long-term operability, reliability, and ease of material handling of the CST with wood (pallets), DPE suits, and carbon (filter trays);
- Observing the effectiveness of the proposed full-scale control strategy for the CST;
- Observing the ability of the CST to reach a 5X condition throughout the feed material;
- Verifying critical design parameters (e.g., temperature, steam flow rate, CatOx loading, feed throughput rate) developed during demonstration testing;
- Observing the ability of the CatOx unit to effectively treat the uncondensed gases over long-term operation;
- Determining the expected CatOx catalyst life under continuous CST operation; and
- Characterizing neutralized CST condensate for selected chemical constituents and physical parameters and the presence or absence of hazardous and toxic chemicals, including Schedule 2 compounds.

#### **5.2.2.4.5 Catalytic Oxidation Unit**

Planned EDS activities for the CatOx unit consisted of the following:

- Observing the long-term (500 hours) operation of the CatOx unit with HD,
- Determining whether the CatOx unit catalyst loses efficiency (due to poisoning, fouling, and/or plugging),
- Determining the expected CatOx catalyst life under continuous HD operation, and

- Determining (via characterization) the ability of the CatOx effluent to be treated by a downstream carbon bed.

Additional testing of the neutralization/biotreatment system was planned during EDSs and included the following:

- Water washout of mustard agent projectiles,
- Biotreatment of propelling charge hydrolysate, and
- MPT treatment of inert hardware.

The results of the EDSs for neutralization/biotreatment were not included in this TRD.

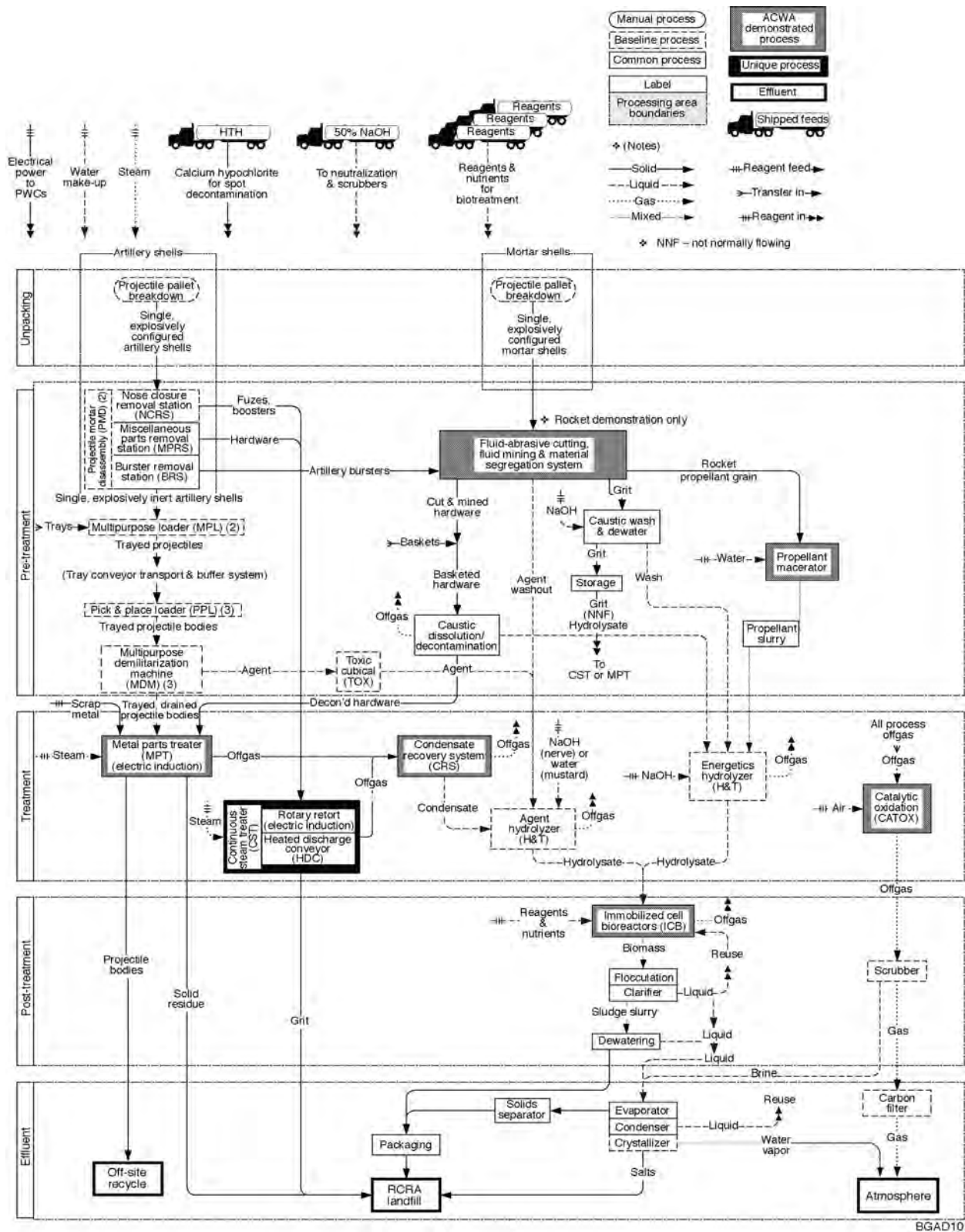
#### **5.2.2.5 Detailed Process Description**

This section presents a detailed process description for neutralization/biotreatment as applied to BGAD and the ACW containing mustard agent stored there, on the basis of the results of demonstration testing.

Figure 5.10 illustrates the entire process flow for the neutralization/biotreatment process. As the figure shows, neutralization/biotreatment would start with munition pretreatment, which uses baseline reverse assembly, fluid-abrasive cutting, and fluid-mining. Projectiles would be accessed by baseline reverse assembly. A modified multipurpose demilitarization machine (MMDM) would be used to access and drain the agent cavity. Projectile fuzes and bursters would be removed with the propellant macerator device. The fuzes would be fed to the CST, and the bursters would be fluid-mined with water.

Projectiles, basketed munition hardware, dunnage, and other solid wastes would be thermally decontaminated to a 5X condition in either the MPT, an inductively heated vessel with a superheated steam reactive environment, or the CST, a rotary version of the MPT with a similar structure to the baseline DFS. Steam would be condensed from the MPT or CST off-gas and sent to the CRS. Water with a caustic wash would be used to neutralize mustard agent, and NaOH would be used for nerve agent and energetics. Neutralization would occur in CSTRs, similar to the U.S. Army's ATP process. Drained agents and CRS effluents would be treated in the agent hydrolyzer, while slurried energetics (from cutting, mining/washing) and spent abrasive wash would be treated in the energetics hydrolyzer.

Agent and energetic hydrolysates would be adjusted for pH, combined, and mixed with reagents and premixed nutrients for aerobic digestion (biotreatment) in the ICB. For all agents,



**FIGURE 5.10 Flow Diagram of Entire Neutralization/Biotreatment Process at BGAD (Adapted from PMACWA 1999b,c)**

the clarifier side stream would then be sent to water recovery, where it would be evaporated to concentrate the salt content. Sludge from the ICB would be dewatered, packaged, and disposed of as hazardous waste in a hazardous waste landfill.<sup>35</sup> Liquid from sludge dewatering would be sent to the recovered water storage tank for reuse. All process off-gas would be mixed with air and catalytically converted by the CatOx technology, followed by release to the atmosphere. Oxidized liquid and scrubber brine would be dried — first concentrated by evaporation, with water condensed and reused — followed by crystallizing; water vapor would be released to the atmosphere, and dry salts would be sent to a RCRA facility for further treatment, if necessary, and disposal. Treated munition bodies (5X condition) may be commercially recycled, and treated solid wastes (3X or 5X condition) may be disposed of as either hazardous or nonhazardous waste, depending on regulatory requirements.

Short descriptions of each of the unit processes included in the neutralization/biotreatment process are provided in the following subsections. Parsons/Allied Signal (1999), which includes detailed process flow diagrams, may be viewed for additional detail.

#### **5.2.2.5.1 Munitions Access**

The proposed design for munitions access incorporates many of the units used in baseline reverse assembly (See Appendix E of Volume 1 for details). Units include reverse assembly machines, material handling conveyors, robotic loaders and handlers, HDCs, elements of the MPF thermal treatment system, auxiliary systems, and facilities and support systems. Some of these units have been slightly modified from the baseline process, but the basic unit and operations have been retained. The major units are summarized below.

The PMD machine and supporting equipment have been adopted without modification. The PMD is a custom-designed, automated machine that uses a turntable to position munitions at the various workstations arranged around the perimeter of the machine. Munitions would be processed in a horizontal position, and fuzes, nose closures, supplementary charges, bursters, and other energetics would be removed.

Bursters would be conveyed to the multistation fluid-accessing machine, where energetics would be removed through the fuze end of the item by a high-pressure multijet fluid nozzle using water. The multistation fluid-accessing machine would replace the baseline BSRM.

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<sup>35</sup> This sludge may be defined as hazardous waste if it exhibits any of the characteristics of hazardous waste as defined in 40 CFR 260.21 – 260.24. This sludge may contain heavy metals and may exhibit the RCRA toxicity characteristic (40 CFR 261.24). In Kentucky, the sludge may be regulated as listed hazardous waste because of its association with chemical agent. If the sludge is listed as hazardous waste, a RCRA delisting petition may be pursued to reclassify the waste as nonhazardous.



Empty burster casings would be sheared in the burster shear station. The munitions would then be transported to the MMDM, where the burster well would be pulled from the item, thereby exposing the agent. The agent would then be drained using aspiration. The burster well would be crimped, placed back into the munition body, and conveyed to the MPT. The fuzes and burster casings would be sent to the rotary version of the MPT, the CST. Agent would be conveyed to holding tanks in the toxic cubicle (TOX), where it would be stored prior to introduction to the agent hydrolyzer. Energetics washout would be conveyed to the energetics hydrolyzer.

#### **5.2.2.5.2 Agent Treatment**

An agent hydrolyzer would be used for agent treatment. Hydrolysis would be conducted in a CSTR, which is similar to the unit used for energetics treatment. The feed would be added to the CSTR, which would contain water at the required reaction temperature. Batches would be adjusted, as necessary, and then released to storage prior to biotreatment. The neutralization technology would incorporate the ATP neutralization system design that will be used at APG, with minor modifications to interface with other equipment. It is chemically identical to that used in neutralization/SCWO (see Section 5.2.1) and in neutralization/GPCR/TW-SCWO (see Section 5.3.3).

Secondary treatment of the agent hydrolysate to remove Schedule 2 compounds would be accomplished using biotreatment. Both the agent hydrolysate and energetics hydrolysate would be treated in the same bioreactor. Concentrated hydrolysates from these operations would be stored until they were fed to the bioreactor. Recovered water would be added, as well as nutrients needed by the microbes used to biotreat the hydrolysates. The bioreactor would process the hydrolysates and pass a clean effluent on to the water recovery operation.

The ICB used for biotreatment would be a proprietary reactor. However, other biotreatment processes may be substituted for the proposed biotreatment system. Agent and energetic hydrolysates would be combined in the ICB feed tank with a premixed nutrient solution. This feed would be continuously metered to the bioreactor. Outside air would be forced through the reactor beds. Bioreactor effluent would be taken to a flocculation unit where sludge would be precipitated out and prepared for removal. The reagent used (Fenton's reagent) would also remove color and odor from the bioreactor effluent. A clarifier would be used to remove the sludge as a slurry that would be pumped to a water recovery unit. Clarifier overflow would be pumped to a recycled water storage tank for subsequent reuse in the system. Biosolids and biosalts would be solidified and placed in a landfill as hazardous waste. Noncondensable gases from this system would be passed through the catalytic oxidation unit (CatOx) prior to release to the atmosphere.

#### **5.2.2.5.3 Energetics Treatment**

The energetics hydrolyzer would be the main element for primary treatment of energetics. The energetics hydrolyzer would replace the baseline DFS but has been adapted to the same interfaces with other equipment as the DFS. The energetics hydrolyzer is similar in design and operation to the agent hydrolyzer and would receive washed-out energetics from the multistation fluid-accessing machine.

The feed would be added to the hydrolyzer, which would contain NaOH solution at the required reaction temperature. After the required reaction time, a sample of the hydrolysate would be analyzed for agent and energetics. Batches would be additionally treated, as necessary, and then released to storage prior to biotreatment. Biotreatment would follow the same process as discussed above for agent hydrolysates.

#### **5.2.2.5.4 Metal Parts Treatment**

The metal parts from munitions access would be processed by the MPT, which would either be a tube-type or rotary device that is induction heated. In the MPT, projectile and mortar bodies would be decontaminated to a 5X condition in a superheated steam atmosphere. Induction coils would be used to ramp up the temperature through a prescribed cycle. Volatile liquids would be vaporized and removed by the steam, which would be condensed downstream in the CRS.

The liquid condensate from the CRS would be taken to the SDS where it would be diluted with a low concentration alkaline solution of the spent decontamination fluid and subsequently added as makeup water to the agent hydrolyzer. Noncondensable gases would be processed through catalytic converters (the CatOx system).

Energetic hardware, specifically fuzes, nose closure plugs, projectile burster casings, and fuze booster cups, would be processed through a similar device, the CST. As indicated previously, this unit would be a modified version of the MPT and can operate in continuous feed mode.

#### **5.2.2.5.5 Dunnage Treatment**

Dunnage would be treated during the campaign to the extent possible. The dunnage would be thermally treated in a steam environment in the MPT. Although not all dunnage would be agent-contaminated, all dunnage would be treated on-site in this manner.

#### **5.2.2.5.6 Effluent Management and Pollution Controls**

The effluent management and pollution control systems used in neutralization/biotreatment would be similar to those used in the baseline incineration plant (See Appendix E of Volume 1). Included are scrubbers, condensers, and carbon filters, which would be used to remove residual organics from contaminated areas before discharge to the atmosphere. The neutralization/biotreatment system would also include a CatOx system, which would be used to treat organic constituents within the air stream. Two different CatOx units would be employed. One would be used for the bioreactors, and the other would be used for all other systems. Both CatOx units would operate in an identical manner.

The CatOx units that would be used for the bioreactors are not intended to treat agent. They are provided solely to treat organic compounds that would emanate from the ICB feed or that would be generated during the biodegradation process. Incoming air streams would be heated electrically to reduce moisture and to condition the gas to the CatOx operating temperature. The catalytic matrix within the device is designed to reduce organic materials to basic elements. The bioreactor CatOx units would discharge directly to the atmosphere (no scrubbers or carbon filtration) since it is unlikely that they would receive any chemical agent (Parsons/Allied Signal 1999). The CatOx unit used for the other systems in the neutralization/biotreatment process may vent to the scrubber/carbon filter system as a precaution.

All other systems would be identical to the baseline system, including the supplied air and personnel support systems, the plant instrument air supply and steam supply systems, control rooms, the process for handling munitions from storage to the facility, personnel support, monitoring systems, and analytical laboratories.

#### **5.2.2.6 Common Elements – Other Systems**

The neutralization/biotreatment process has several elements that are identical or nearly identical to other systems. Commonalities with other applicable technology systems include the following:

- The munitions access system used for neutralization/biotreatment employs much of the baseline reverse assembly system, as do the other ACWA systems, and
- Neutralization/SCWO (see Section 5.3.2), neutralization/biotreatment (see Section 5.3.3), and neutralization/GPCR/TW-SCWO (see Section 5.3.4) systems employ neutralization of chemical agents and energetics.

- The neutralization/biotreatment process and the electrochemical oxidation process each employ fluid-abrasive cutting and fluid-mining to access munitions. In addition, both technology systems employ superheated steam treatment for metals and solids to achieve a 5X condition.
- The neutralization/biotreatment, the neutralization/GPCR/TW-SCWO, and electrochemical oxidation processes each employ a catalytic technology as well.

Facility structure; ventilation; decontamination fluid supply; personnel support; pollution abatement; water, air, and steam supply systems; control rooms; monitoring systems; and laboratory support would be identical or nearly identical to the baseline system.

### 5.2.3 NEUTRALIZATION/GPCR/TW-SCWO

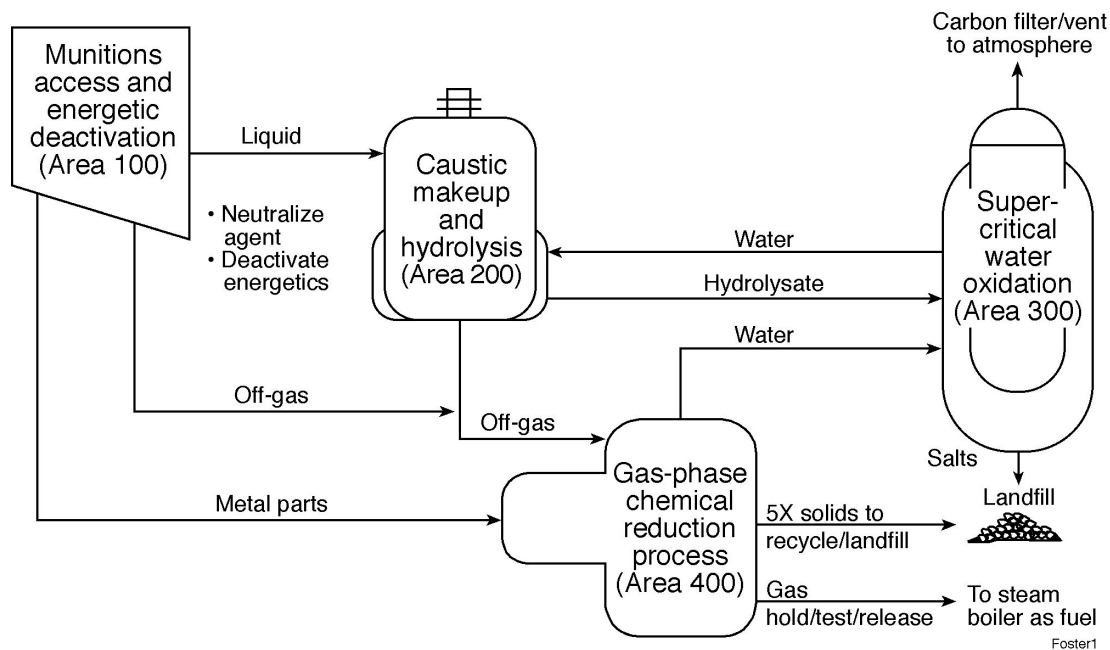
The neutralization/GPCR/TW-SCWO technology system consists of neutralization of agents and energetics, GPCR of solids and gases, and secondary treatment of neutralization residuals using TW-SCWO. This technology is applicable to all ACW stored at BGAD, including ACW containing nerve or mustard agent. This technology was proposed by Foster Wheeler/Eco Logic/Kvaerner.<sup>36</sup> The following subsections provide a more detailed discussion of the technologies and processes involved in this system. The technology provider's technology demonstration report (Foster Wheeler/Eco Logic/Kvaerner 2000) may be viewed for additional detail.

#### 5.2.3.1 Process Overview

The neutralization/GPCR/TW-SCWO process, as applied to projectiles and rockets stored at BGAD, is summarized in Figure 5.11. ACW at BGAD would be disassembled by using a modified baseline reverse assembly process. For projectiles, the energetic materials would be removed and the agent would be drained. This would be accomplished using the baseline PMD and a Projectile Punch Machine (PPM). For rockets, the baseline RSM would be used; however, it has been modified (MRSM) for this application. Agent would be drained from the rockets via a punch and drain process. Then the rocket would be sheared to access the fuze and burster. A tube cutter would be used to section the fiberglass rocket firing tube just forward of the threads of the fin assembly, and the fin assembly would be unscrewed to access the propellant. Propellant would be pulled from of the rocket motor, size-reduced in a grinder, and slurried.

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<sup>36</sup> Foster Wheeler, Eco Logic, and Kvaerner were originally part of a larger team under the coordination of Lockheed Martin (PMACWA 1997, 2001a). Lockheed Martin is no longer part of the technology provider team.



**FIGURE 5.11 Overview of Neutralization/GPCR/TW-SCWO Process (Foster Wheeler/Eco Logic/Kvaerner System) for the Treatment of ACW at BGAD (Source: Adapted from NRC 1999)**

Munitions casings and other hardware would be processed through the Continuously Indexing Neutralization System (COINS™). This system would be used to place munitions casings and other solids in hanging baskets that are dipped in caustic baths to separate energetics from metal parts, followed by spray washing.

The drained nerve agents (GB and VX) would then be neutralized/hydrolyzed by using a NaOH solution in systems operated at 194°F (90°C) and atmospheric pressure. Energetics would be neutralized/hydrolyzed by using a caustic solution in systems also operated at 194°F (90°C) and atmospheric pressure. Mustard agent would be hydrolyzed using hot water; however, caustic would be used later in the process. Hydrolysates would be treated in a TW-SCWO unit. TW-SCWO differs from solid-wall SCWO (see Section 5.2.1) in that a boundary layer of clean water is dispersed from the sides of the SCWO unit as a means of limiting corrosion and solids buildup (Foster Wheeler/Eco Logic/Kvaerner 2000). TW-SCWO also differs from the solid-wall unit in that the TW-SCWO can treat agent and energetic hydrolysates simultaneously.

Dunnage and metal parts (e.g., from COINS) would be treated using GPCR. GPCR is a thermal system operated at temperatures above 1,560°F (850°C) that uses hydrogen in a steam atmosphere to reduce organic compounds to methane (CH<sub>4</sub>), CO<sub>2</sub>, CO, and acid gases. The system includes solids treatment in a thermal reduction batch processor (TRBP), which uses a flame-heated batch evaporator to volatilize organic materials to the main GPCR reactor. The

TRPB would treat metal parts and dunnage to a 5X condition.<sup>37</sup> A batch or continuous mode TRBP may be employed, depending on the nature of the munitions being treated. The technology provider indicates that recovered gas from the GPCR unit may be able to be used as auxiliary fuel for a steam boiler or industrial furnace (BIF) (NRC 1999). (See Section 5.3.5.3.4 for information on recovered gas content.)

Each of these operations is performed in a different area of the destruction facility, as shown in Figure 5.12.

### **5.2.3.2 History of Destructive Processes**

Neutralization, GPCR, and TW-SCWO are the primary destructive processes employed in this technology. The history of these processes is summarized below.

#### **5.2.3.2.1 Neutralization of Agent and Energetics**

Agent and energetics neutralization were reviewed in Section 5.2.1.2. Because the history of neutralization of agent and energetics for neutralization/GPCR/TW-SCWO does not differ from other technologies, this information is not repeated.

#### **5.2.3.2.2 Gas-Phase Chemical Reduction**

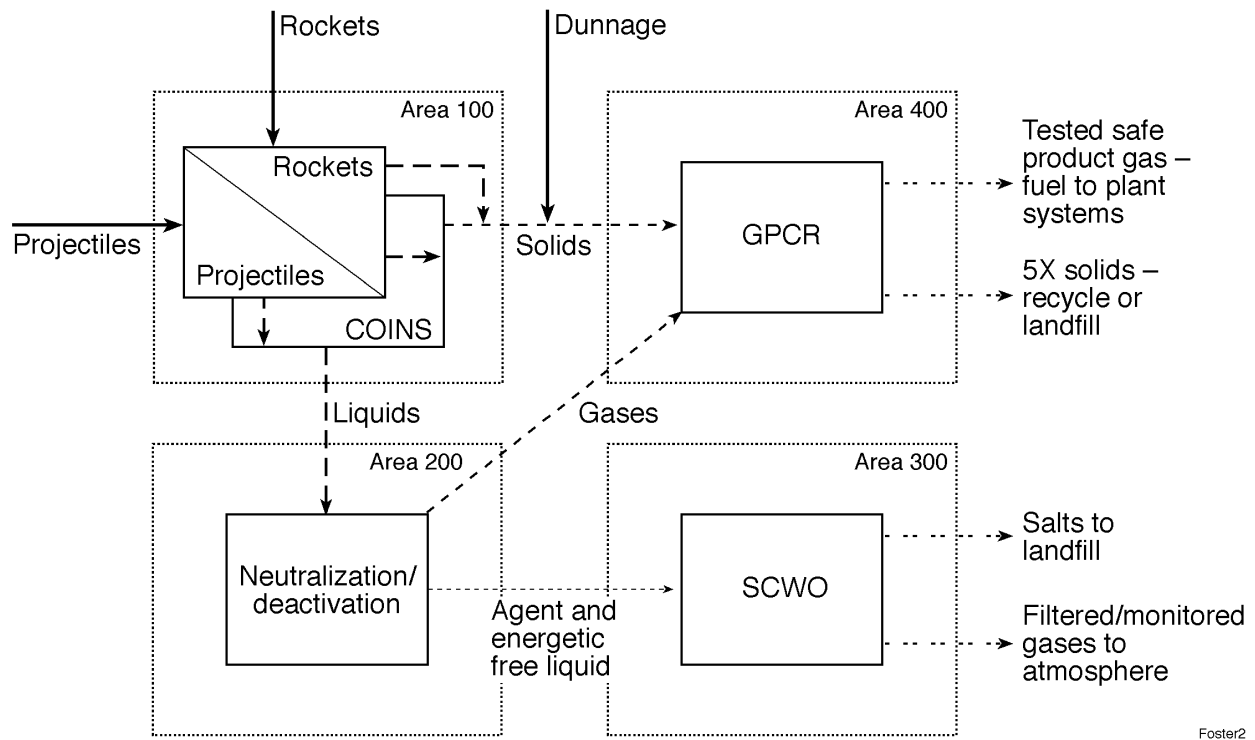
GPCR is used in this technology system as a means of treating solid materials (metal parts and dunnage) and gases from other parts of the facility (from neutralization reactors). The process was developed and patented by Eco Logic (NRC 1999). Figure 5.13 is a simplified flow diagram for a typical GPCR process (Foster Wheeler/Eco Logic/Kvaerner 2000).

GPCR has a history of use in treating waste streams. This technology has been used to treat electrical equipment contaminated with PCBs (NRC 1999). In addition, the process has been used in both Canada and Australia (NRC 1999). The Australian plant currently processes organochlorine pesticide wastes, the major component of which is DDT (Eco Logic 2001).<sup>38</sup> Eco Logic, Inc., indicates that its process was demonstrated at the Middleground Landfill in Bay City, Michigan, under a Toxic Substances Control Act research and development permit during October and November 1992. The test was performed using PCB-contaminated wastewater, waste oil, and soil from the site. Test results yielded a 99.99% DRE for PCBs during all runs; a

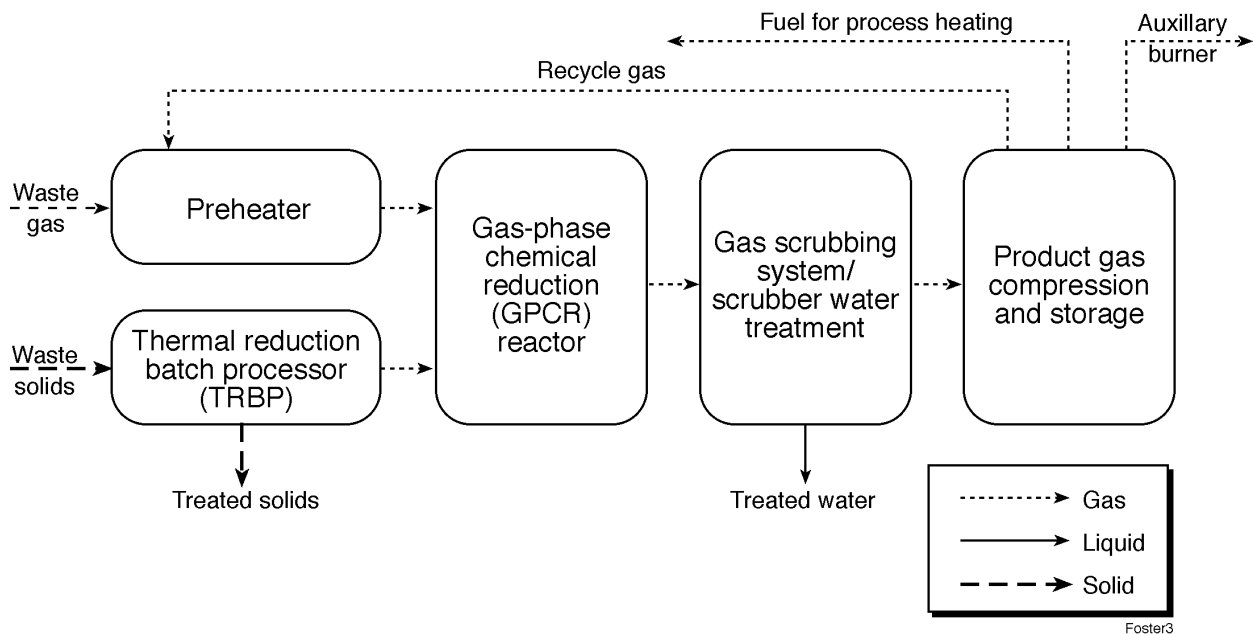
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<sup>37</sup> The definition of 5X is provided in Volume 1 of this TRD (see Section 1.2.2.4).

<sup>38</sup> DDT is a banned pesticide, otherwise known as dichlorodiphenyltrichloroethane.



**FIGURE 5.12 Neutralization/GPCR/TW-SCWO Process Overview Showing Different Areas of the Destruction Facility (Source: Foster Wheeler/Eco Logic/Kvaerner 2000)**



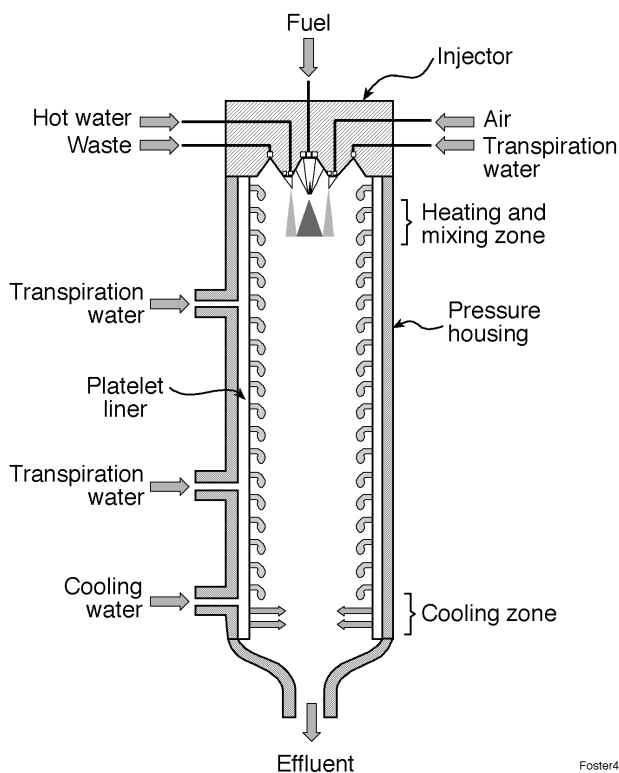
**FIGURE 5.13 Flow Diagram of Gas-Phase Chemical Reduction (GPCR) (Source: Foster Wheeler/Eco Logic/Kvaerner 2000)**

99.99% DRE for a tracer compound (e.g., perchloroethylene); and a net destruction of trace feedstock dioxin and furan compounds during all runs (EPA 1994). Eco Logic has also evaluated the ability of this process to treat chemical agents and energetics considered in the ACWA program, including HD and VX (Eco Logic 1995). The PMACWA indicates that GPCR is expected to gain regulator acceptance (PMACWA 2001a).

### 5.2.3.2.3 Transpiring-Wall Supercritical Water Oxidation

Supercritical water oxidation was reviewed in Section 5.2.1.2. The Foster Wheeler/Eco Logic/Kvaerner approach, however, involves a transpiring-wall (TW) SCWO unit. Figure 5.14 is a schematic of the TW-SCWO unit. The core technology with respect to organic oxidation for TW-SCWO differs only slightly from that of general SCWO. NRC (1998) and NRC (1999) provide information on both processes. Thus, the bulk of the information presented in Section 5.2.1.2 is not repeated here; only that which is unique to TW-SCWO is discussed.

TW-SCWO is a type of SCWO unit that was developed to overcome plugging and corrosion problems associated with conventional SCWO (NRC 1999). The premise behind the unit is that maintaining a layer of clean water between the unit wall and the primary oxidation



**FIGURE 5.14 Transpiring-Wall (TW) SCWO Reactor**  
(Source: Foster Wheeler/Eco Logic/Kvaerner 2000)



reaction limits corrosion and associated plugging. The unit, called a transpiring platelet wall reactor, was developed and patented by GenCorp/Aerojet and Foster Wheeler (NRC 1999). The unit has two walls; an inner TW that is contained within an outer wall. The inner wall consists of a series of platelets that permit continuous transpiration of deionized water into the unit (NRC 1999). Additional details on the device are provided in NRC (1999). NRC (1998) provides an overview of the history of SCWO and TW-SCWO and presents the results of testing using VX and other hydrolysates at PBA. To date, the TW technology has not been commercially used.

### 5.2.3.3 Demonstration Testing<sup>39</sup>

As discussed for the other technology systems presented in this TRD, baseline reverse assembly, carbon filtration, and the BRA were not demonstrated as part of the demonstration program. Other unit operations proposed for the neutralization/GPCR/TW-SCWO system were also not selected for demonstration. The following unit operations proposed for neutralization/GPCR/TW-SCWO were not selected for demonstration by the PMACWA for the reasons given below.

**Punch Machine.** The projectile punch machine (PPM) is a new addition to the proposed full-scale process and was incorporated after demonstration had been conducted.

**Projectile Burster Washout.** This operation is substantially similar to the burster washout technology previously validated by the PMACWA.

**MRSRM.** The MRSRM is a new addition to the proposed full-scale process and was incorporated after demonstration had been conducted. It is also based on the existing baseline RSM process.

**Propellant Grinding.** Several ACWA technologies will require size reduction of M28 propellant. Therefore, the PMACWA has elected to conduct a single design study to address this requirement for these technologies.

**COINS.** Originally, during the initial preparations for Demo I in 1998, the technology provider (led by Lockheed Martin) proposed demonstration of caustic hydrolysis of energetic materials contained in fuzes and bursters, and in propellant from rockets and projectiles. However, after the team was reformed in late 1999, the PMACWA decided to discontinue the demonstration of caustic hydrolysis on the basis of the success of Demo I. Data gathered during the PMACWA's Demo I activities demonstrated the ERH system (PMACWA 2001b) and the

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<sup>39</sup> This material describes the Demo II PMACWA program and was derived, in part, from PMACWA (2001b). Because demonstration testing was intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

batch energetics hydrolysis at Pantex and the Radford Army Ammunition Plant (PMACWA 2001b).

The reasons for selecting the neutralization/GPCR/TW-SCWO demonstration unit operations, testing objectives, and significant deviations from the planned testing are discussed in the following subsections.

#### **5.2.3.3.1 Agent Hydrolysis**

The PMACWA previously demonstrated agent hydrolysis extensively in its ATP and during Demo I. For Demo II, the PMACWA ran agent hydrolysis units to provide representative feedstock for TW-SCWO and to characterize the intermediate product stream for residual agent, Schedule 2 compounds, and other substances required to verify the mass balance. The specific test objectives of these demonstration units included the following:

- Use the hydrolysate recipes developed and tested by the ECBC;
- Characterize solid, liquid, and gas process streams; and
- Provide agent hydrolysate in support of demonstration testing.

During Demo I, GB and VX hydrolysate were produced in the 100-gal (379 L) batch reactor at CAMDS. The design and manufacture of a hydrolysis system provided information on equipment and operational parameters for use in scale-up to a full-scale facility (PMACWA 2001b). VX and GB hydrolysate remaining from Demo I were shipped to DPG for the TW-SCWO demonstration.

For Demo II, HD hydrolysate was produced at the CTF (APG). The equipment used was not intended to model scale-up to a full-scale facility, but was an expedient design suitable for use in the contained environment of the CTF. The HD hydrolysate was shipped to DPG for the TW-SCWO demonstration (Dalton 2000).

There were no significant deviations from the planned demonstration testing.

#### **5.2.3.3.2 Energetics Hydrolysis**

Other government agencies have previously demonstrated energetics hydrolysis. Energetics hydrolysis was also demonstrated during Demo I for a variety of feedstocks

(PMACWA 2001b). Hydrolysis of M28 propellant, Composition B, and tetrytol (using 6% or 12% NaOH) was validated during Demo I.

During Demo II, feedstocks were similarly required for the TW-SCWO testing. The specific test objectives of these demonstration units included the following:

- Produce energetics hydrolysate for use as feed material in subsequent demonstration testing;
- Characterize solid, liquid, and gas process streams; and
- Gather process operation information to support the ACWA program and future scale-up.

Tetrytol and cyclotol hydrolysate were produced at Pantex and shipped to DPG for the TW-SCWO demonstration. Cyclotol was an alternate for Composition B, since it contains comparable amounts of cyclotrimethylenetrinitramine (RDX) and 2,4,6-trinitrotoluene (TNT).

The Radford Army Ammunition Plant produced 16.7% M28 propellant in 12% caustic hydrolysate. M28 hydrolysate was shipped to DPG for the TW-SCWO demonstration.

There were no significant deviations from the planned demonstration testing.

#### **5.2.3.3.3 TW-SCWO Energetics/Agent Hydrolysate**

The basic ability of SCWO to destroy agent and energetics hydrolysates separately was demonstrated previously (PMACWA 2001b). TW-SCWO was demonstrated to validate the effectiveness of the transpiring-wall unit design for treating combined hydrolysate of agent and energetics.

The TW-SCWO reactor mixes feed materials, water, oxidant, and fuel under supercritical conditions. At supercritical conditions, these four materials are completely miscible and form a single phase with physical properties (high density, low viscosity) that are conducive to rapid oxidation. The TW-SCWO platelet reactor is designed to protect the walls from corrosion and to minimize plugging of the unit. Clean, high-pressure water is forced through passages in the wall and is metered through thousands of injection points in the perforated liner. The injected water is supposed to form a barrier between the liner and reaction products flowing through the reactor. Near the exit of the reactor, water at 60°F (15°C) is injected into the reactor to rapidly quench the effluent to 600°F (315°C). This causes most precipitated salts exiting the reactor to redissolve into the water. The cooled effluent then enters a flash gas separator. Gaseous effluents are scrubbed in carbon filters and released to the atmosphere. Liquid effluents containing soluble and

insoluble salts and metal oxides were collected and analyzed. The demonstrated TW-SCWO operated with a hydrolysate feed rate of 60 lb/h (27 kg/h); 46 to 87 lb/h (21 to 87 kg/h) of auxiliary fuel (kerosene) was added (depending on the feed) to increase the heating value of the feed. VX hydrolysate simulant was processed for 100 hours.

Characterization of gaseous, liquid, and solid effluents and verification of operating parameters were required. The objectives of the demonstration testing included the following:

- Demonstrate long-term, continuous operability of TW-SCWO with respect to salt plugging and corrosion in the reactor, effects of operation on the TW liner, and erosion of the pressure control valve;
- Determine whether aluminum from the energetic hydrolysis process can be processed by TW-SCWO without plugging;
- Demonstrate the ability of TW-SCWO to destroy Schedule 2 compounds present in the hydrolysate feed; and
- Characterize the gas, liquid, and solid process streams from TW-SCWO.

Four different mixes of agent hydrolysate simulant or mixed agent/energetics hydrolysate were processed through TW-SCWO. Continuous, long-term (100 hours) runs were intended to be performed to meet the objectives. The length of these continuous runs required quantities of feed that exceeded the DPG treatability study permits; therefore, the agent hydrolysates were supplemented by simulants. The feeds included the following:

- VX Hydrolysate Simulant. 13.2% dimethyl methylphosphonate (DMMP), 15.3% sodium isothionate, 9.8% diethanolamine, 3.1% isopropanol (70% solution), 18.0% NaOH (50% solution), and 40.6% water.
- HD/Tetrytol/Aluminum Hydrolysate. Simulated combined agent (HD) and energetic (tetrytol) hydrolysate obtained from an M60 105-mm projectile. Actual agent hydrolysate was used for the first 19 hours, at which time it was replaced by a mixture of 10.01% thiodiglycol and 9.58% sodium chloride (NaCl) in water; NaOH was added to bring the pH of the mixture to 11.
- GB/Cyclotol/Aluminum Hydrolysate. Simulated combined agent (GB) and energetic (cyclotol) hydrolysate obtained from an M426 8-in. projectile. Actual agent hydrolysate was used for the first 28 hours, at which time it was replaced by a mixture of 6.37% DMMP, 2.15% sodium fluoride (NaF), 2.60% NaOH, 1.03% isopropanol, and 0.77% tri-n-butylamine in water.

- VX/Cyclotol/M28 Propellant/Aluminum Hydrolysate. Simulated combined agent (VX) and energetic (cyclotol and M28 propellant) hydrolysate obtained from an M55 rocket. Actual agent hydrolysate was to be used for the first 79 hours, at which time it was to be replaced by VX hydrolysate simulant.

Significant deviations from the planned demonstration testing included the following:

- The HD/tetrytol/aluminum hydrolysate test was terminated after 55 hours because of concern over the remaining life of the reactor upper liner. During the earlier workup run with this feed, a region at the top of the upper liner (unprotected by transpiring water) cracked and had to be replaced. It was replaced with a spare lower liner segment modified for use as the upper liner. At the end of 55 hours of the validation test, the new upper liner exhibited significant deformation in the form of a bulge near the top of the liner.
- The GB/cyclotol/aluminum hydrolysate was run continuously for only 50 hours rather than the 100 hours objective; this was a planned change made at the end of the previous run.
- The VX/cyclotol/M28 propellant/aluminum hydrolysate validation run was terminated just short of 26 hours primarily because of continued feed flow problems, high effluent temperatures from heat exchanger fouling, and trouble with the reactor injector ports. No serious corrosion or salt plugging occurred within the reactor.

#### 5.2.3.3.4 Gas-Phase Chemical Reduction Reactor

The GPCR technology consists of the TRBP and the reactor, which can be characterized as an electrically heated cyclone.<sup>40</sup> GPCR was demonstrated to validate the effectiveness of the process for heating metal parts and dunnage to a 5X condition in the TRBP and for treating the gaseous effluent in the hot, reducing environment of the reactor to destroy any residual agent and energetics.

In the TRBP, contaminated materials and metal parts are heated to 1,110°F (600°C). Organic compounds are volatilized and swept into the reactor by the hydrogen purge gas that is maintained in the TRBP. Metal parts are held at temperatures above 1,000°F (538°C) for at least 15 minutes to achieve a 5X condition. In the GPCR reactor, the gas-phase reduction of organic compounds occurs in the presence of hydrogen at temperatures above 1,560°F (850°C). Organics

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<sup>40</sup> A cyclone is a device that is designed to spin a gas stream at a high rate of speed in order to remove entrained particles by using centrifugal force.

are reduced to CH<sub>4</sub>, acid gases, and small amounts of simple hydrocarbons. Blister agents (H, HD, and HT) and nerve agents (VX and GB) are chemically reduced to CH<sub>4</sub>, HCL, hydrogen sulfide (H<sub>2</sub>S), H<sub>3</sub>PO<sub>4</sub>, steam, N, and hydrogen fluoride (HF)<sup>41</sup>. Although not demonstrated, NO<sub>x</sub> produced from the decomposition products of propellants and explosives should be converted to gaseous nitrogen and steam. Process gas leaving the top of the reactor is scrubbed in two caustic scrubbers to remove acid gases, water, heat, and fine particulates. The acid gases are neutralized to form common salts. The setup for GPCR included three TRBPs of various sizes and one reactor with a common gas scrubber system.

Characterization of gaseous, liquid, and solid effluents and verification of operating parameters were required. The objectives of the demonstration testing included the following:

- Demonstrate the ability of GPCR to achieve a 5X condition for metal parts and dunnage;
- Demonstrate the effectiveness of GPCR for treating the gases generated during the processing of metal parts and dunnage;
- Validate the ability of GPCR to achieve a DRE of 99.9999% for HD and GB;
- Demonstrate the ability of GPCR to produce a gas effluent that meets U.S. Environmental Protection Agency (EPA), Syngas, or BIF requirements;
- Characterize gas, liquid, and solid process streams from GPCR for selected chemical constituents to determine the absence or presence of hazardous, toxic, agent, and Schedule 2 compounds; and
- Determine the need for stabilization of residual dunnage solids on the basis of toxicity characteristic leaching procedure (TCLP) results.

GPCR was tested with the following material:

- 150-lb (68-kg) carbon trays (1 tray for each of 3 runs),
- 66-lb (30-kg) wood spiked with 4,000 ppm PCP (22 lb [10 kg] for each of 3 runs),

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<sup>41</sup> HF is produced only when GB is treated.

- 54-lb (241-kg) double-bagged DPE with butyl rubber to simulate boots and gloves (16.5-lb [7.5-kg] DPE suits with 1.65-lb [0.75-kg] butyl rubber and 4 plastic bags for each of 3 runs),
- 12-lb (5-kg) fiberglass storage and firing container tubes (1/4 tube, or 4 lb [2 kg] for each of 3 runs),
- 32-lb (15-kg) GB (10.8-lb [4.9-kg] agent for each of 3 runs), and
- Two mortars filled with a 30% HD heel (15.5-lb [7.0-kg] metal with 1.8-lb [0.81-kg] HD per mortar).

Significant deviations from the planned demonstration testing included the following:

- The first validation run with DPE was terminated before a 5X condition was achieved, because a rise in system pressure was observed due to a blockage that formed in the gas line between the TRBP and the reactor.
- The third validation run with a mortar and HD heel was not conducted because of schedule constraints.
- The product gas stream and the stack gas stream could not be completely characterized. The results of agent analysis in the gas stream were inconclusive; consequently, the gas samples could not be sent off-site to contract laboratories for analysis of nonagent-related constituents and, therefore, were analyzed by nonstandard analytical methods. Most of the stack gas analyses (all except oxygen [O<sub>2</sub>], CO<sub>2</sub>, and CO) and some of the product gas analyses (phosphine, HF, and hydrogen cyanide) were not conducted during the GB and HD validation runs.

#### **5.2.3.3.5 Summary of Demonstration Testing**

In summary, demonstration testing during Demo II was not as extensive as testing during Demo I because of the similarity of some of the unit processes and technologies. Agent hydrolysis and energetics hydrolysis objectives were met. Much of the testing of the TW-SCWO unit was performed with agent simulant rather than with agent. Operational problems with the TW-SCWO unit included liner integrity, feed flow problems, high effluent temperatures, and slugging of reactor injection ports. Scaling/lining of the equipment downstream of the SCWO reactor was also shown to be problematic during demonstration testing. However, there was no serious corrosion or salt plugging observed within the reactor. The GPCR unit performed with minor problems; however, the product gas and stack gas streams could not be adequately

characterized for chemical agents or nonagent-related constituents because of difficulties with on-site analyses. Most of the stack gas analyses and some of the product gas analyses were not conducted for GB and HD validation runs. The PMACWA reviews the quality of the data generated during demonstration testing in PMACWA (2001d,e,f).

On the basis of demonstration testing, the technology provider plans to make the following changes to the neutralization/GPCR/TW-SCWO technology (Foster Wheeler/Eco Logic/Kvaerner 2000):

- Identify and finalize an analytical device and method to evaluate product gas from the GPCR unit for the presence of chemical agent;
- Demonstrate the effectiveness, operability, and cleanout cycles of the new GPCR device; and
- Incorporate equipment downstream of the TW-SCWO unit to remove aluminum and other solids.

#### **5.2.3.4 Engineering Design Studies<sup>42</sup>**

During the demonstration testing described above, neutralization/GPCR/TW-SCWO was demonstrated to be a viable technology system for destruction of ACW, in accordance with the requirements of the PMACWA. However, the PMACWA determined that further studies would be necessary in preparation for full-scale pilot design and permitting. Therefore, EDSs will be conducted to provide this information. EDS-II objectives were as follows:

- Provide information for the full-scale facility with respect to total life-cycle cost, schedule, and safety;
- Support the EIS and permit application preparation under RCRA; and
- Support preparation of a RFP for a full-scale pilot plant facility.

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<sup>42</sup> This material describes EDSs for the technologies evaluated in the Demo II PMACWA program and was derived, in part, from PMACWA (2001a). EDSs for Demo II technologies are designated EDS-II. Because demonstration testing was intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.



Agent and energetics neutralization studies that were planned for EDS-I are applicable to the neutralization/GPCR/TW-SCWO technology. These included the activities discussed in the following two subsections.

#### **5.2.3.4.1 Energetics Hydrolysis**

Planned EDS activities for energetics hydrolysis consisted of the following:

- Addressing PMACWA and NRC (NRC 2000) concerns regarding particle size, solubility, by-products that would be produced as a function of time, control strategies, mixtures of energetics, and caustic concentrations; and
- Acquiring information for scale-up.

#### **5.2.3.4.2 Agent Hydrolysis**

Planned EDS activities for agent hydrolysis consisted of the following:

- Determining the potential to use 15% by weight mustard agent hydrolysate for feed to the SCWO unit for increased throughput.<sup>43</sup>

EDS-II are expected to be under way on or about the date of publication of this TRD. Consequently, only preliminary plans for EDS-II are discussed here. Plans for EDSs were summarized from PMACWA (2001a). Figure 5.15 provides an overview of the neutralization/GPCR/TW-SCWO process and shows units or operations that were planned for EDS-II. Planned evaluations of units or operations would be independent of munition type or agent fill.

The following EDS-II activities were planned for neutralization/GPCR/TW-SCWO.

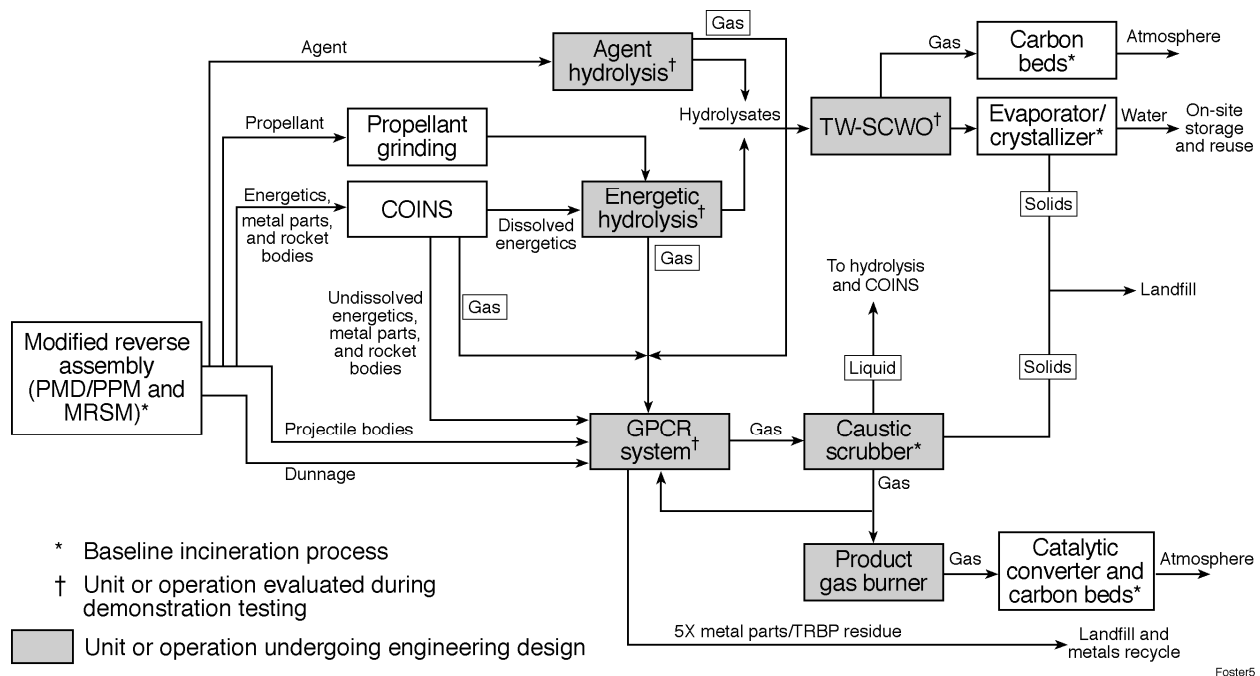
#### **5.2.3.4.3 Munitions Access**

Planned EDS-II activities for munitions access included the following:

- Grinding of M28 propellant.

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<sup>43</sup> 15% hydrolysate mustard loading of the TW-SCWO unit was also demonstrated during Demo II.



**FIGURE 5.15 Flow Diagram of Neutralization/GPCR/TW-SCWO Process (Foster Wheeler/Eco Logic/Kvaerner System) Showing Units or Operations Undergoing Engineering Design (Source: Adapted from PMACWA 2001c)**

#### 5.2.3.4.4 TW-SCWO

Planned EDS-II activities for TW-SCWO included the following:

- Optimization and operability (500-hour runs) tests,
- Effluent salt cake characterization (evaporator/crystallizer), and
- Methods and process monitoring development.

#### 5.2.3.4.5 GPCR

Planned EDS-II activities for GPCR included the following:

- Agent methods and process monitoring development,
- Construction material 500-hour tests, and

- Explosivity tests.

As indicated previously, the results of EDSs for neutralization/GPCR/TW-SCWO were not included in this TRD.

### 5.2.3.5 Detailed Process Description

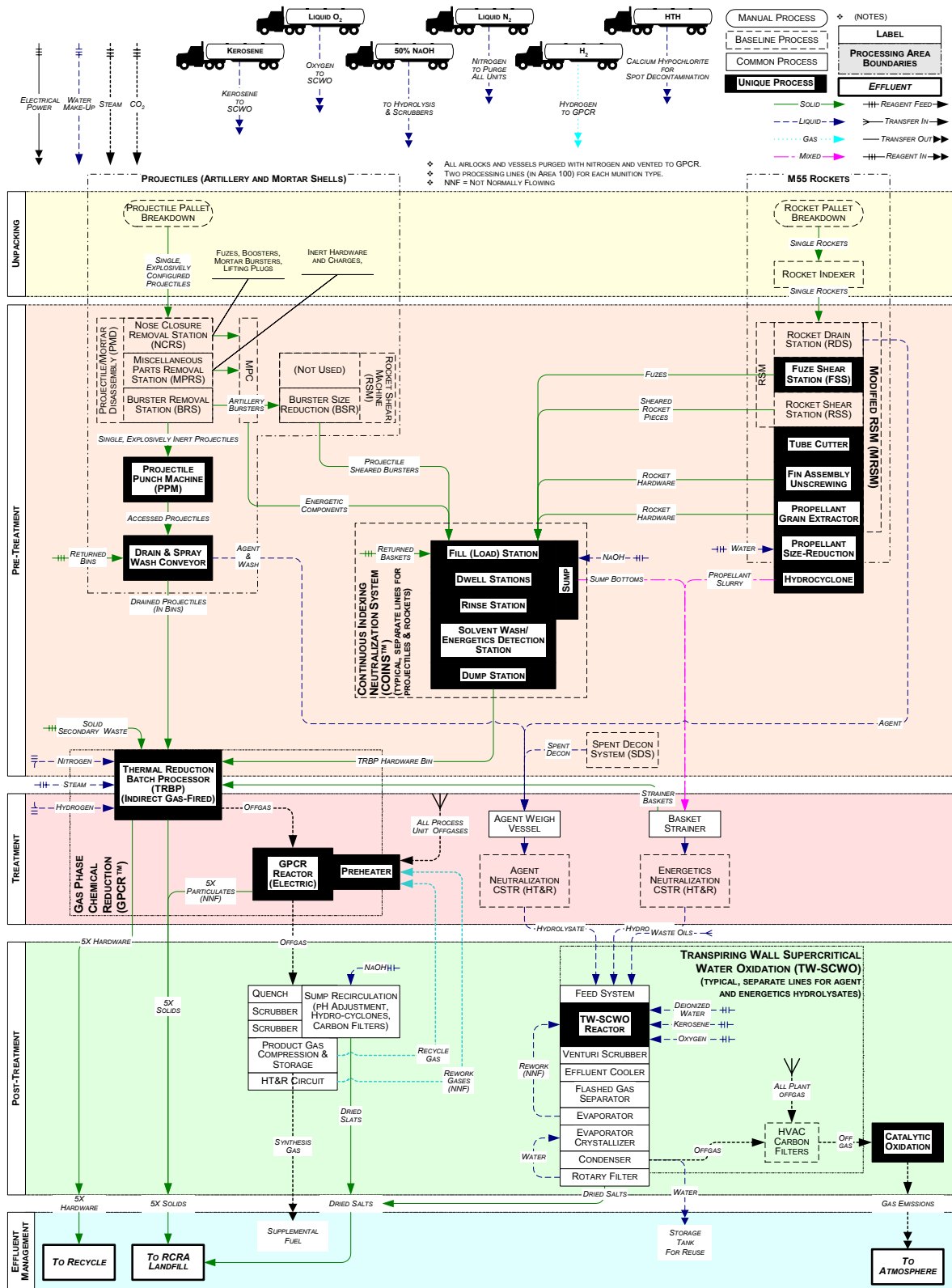
This section presents a detailed process description for neutralization/GPCR/TW-SCWO, as applied to BGAD and the ACW stored there, on the basis of demonstration testing results. The equipment used in a pilot-scale facility may vary in nomenclature and design from that described here, depending on the system selected and system requirements.

Figure 5.16 illustrates the entire process flow for the neutralization/GPCR/TW-SCWO process, as applied to BGAD and the ACW stored there. As indicated previously in Figure 5.12, the technology system is segregated into four primary areas.<sup>44</sup> Munitions access and initial treatment of munitions hardware (e.g., empty casings) would be conducted in Area 100. Munitions access would use modified baseline reverse assembly; a different process would be used for projectiles versus rockets. M28 propellant from the M55 rockets would be pulled out of the rocket motor for subsequent neutralization in Area 200. Energetics from projectiles and the rocket burster, as well as other munitions hardware, would be treated with caustic in the COINS to extract and initiate neutralization of energetics and to neutralize agent remaining after the drain process. Following munitions access in Area 100, the process for treating specific agents and energetics would be largely independent of munition type and agent fill.

Drained agents and M28 propellant from the M55 rockets would be neutralized in Area 200. Caustic hydrolysis using NaOH would be used to neutralize nerve agent and energetics. Hot water would be used to neutralize mustard agent; however, a caustic wash would be used later in the hydrolysis process. Neutralization would be performed in a series of closed CSTRs. Gases generated in these closed vessels would be piped to the GPCR unit in Area 400. Hydrolysate produced in Area 200 would be piped to Area 300 where it would be further treated with the TW-SCWO unit to remove Schedule 2 compounds and other organics. The agent and energetics hydrolysates may be treated in the same TW-SCWO processing train. Dunnage and other solids from projectiles and rockets would also be treated using the GPCR unit in Area 400. Solids would first be placed in the TRBP to drive off organic compounds and to complete treatment to a 5X condition. Gases would flow from the TRBP to the GPCR unit where they would be reduced in a hydrogen environment.

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<sup>44</sup> A fifth process area, Area 500, would be established for infrastructure and support systems.



**FIGURE 5.16 Flow Diagram of Entire Neutralization/GPCR/TW-SCWO Process at BGAD**  
(Source: Adapted from PMACWA 2001b,c)

Munition bodies (projectiles) decontaminated to a 5X condition can be commercially recycled or disposed of as solid waste. Nonmetal solid waste that is treated to a 5X condition, if defined as hazardous waste, can be placed in a hazardous waste landfill.<sup>45</sup> If defined as nonhazardous wastes, these solid wastes may be disposed of in a nonhazardous waste landfill. Liquid from the SCWO units would be evaporated to drive off water, thereby leaving a crystallized salt. The water would be condensed and recycled to the hydrolysis units, and the salts would be sent to a RCRA hazardous waste landfill.<sup>46</sup> Off-gases from process units (except the TW-SCWO) would vent to the GPCR unit. Off-gases from the GPCR unit would be processed through a series of scrubbers and compressors. The resulting liquefied product gas may be used as a fuel gas in Area 400, assuming it meets regulatory acceptance criteria for BIF. TW-SCWO off-gas would pass through carbon filters and would be released to the atmosphere.

Short descriptions of each of the unit processes included in the neutralization/GPCR/TW-SCWO process as applied to projectiles and rockets stored at BGAD are provided below. Because of the differences in the munitions access process for projectiles versus rockets, separate descriptions of the munitions access process are provided. However, the remaining process descriptions (for agent and energetics treatment, dunnage treatment, metal parts treatment, and effluent management and pollution controls) apply to both projectiles and rockets. Foster Wheeler/Eco Logic/Kvaerner (2000) includes detailed process flow diagrams and may be reviewed for additional detail.

#### **5.2.3.5.1 Munitions Access – Projectiles**

The proposed design for munitions access for projectiles incorporates many of the units and processes used in the baseline reverse assembly processes (see Appendix E of Volume 1 for details). Units and processes include reverse assembly machines, material handling conveyors, robotic loaders and handlers, auxiliary systems, and facilities and support systems. Some of these units have been slightly modified from the baseline process, but the basic unit and operations have been retained. The major operations are summarized below.

The reverse assembly operation would be segregated into a dry area and a wet area. Projectiles would be reverse assembled in the Area 100 dry area. The COINS would be housed in the Area 100 wet area. Projectiles would be disassembled using the standard baseline projectile loading and PMD machines, where the burster and fuze would be removed first. A burster shearing machine would be used to shear the bursters, which would then be processed in

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<sup>45</sup> Solids treated to a 5X condition to remove residual agent may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste as defined in 40 CFR 260.21 – 260.24.

<sup>46</sup> While these salts are not known to contain chemical agent, they may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste as defined in 40 CFR 260.21 – 260.24. Typically, these salts contain heavy metals and exhibit the RCRA toxicity characteristic (40 CFR 261.24). In Kentucky, the salts may be regulated as listed hazardous wastes because of their association with chemical agent. These salts may be “delisted” and not considered hazardous waste.

the COINS. The primary difference from the baseline system would be a modified punch and drain system that would use the new PPM to rapidly drain agent from the burster area. Following agent draining, projectile bodies would go directly to the GPCR unit in Area 400 for 5X treatment.

Sheared bursters and other projectile parts would be processed in COINS, which is unique to this technology system. Projectile parts would enter from the dry area through a fill chute with double-explosive doors. The parts would be dropped into baskets that are processed through COINS on a conveyor system. The conveyor would immerse the basket and the parts in caustic baths (dwell stations), followed by a wash station and a dump station. Parts would be held in the dwell stations until energetics have been dissolved and deactivated. Residual solids (including metal parts) that are not dissolved in COINS would be dumped in a TRBP bin, where they would be tested for remaining energetics. If the residual solids met requirements, they would be sent to the GPCR unit in Area 400 for treatment to a 5X condition. Liquid and sludge from the COINS system would be pumped to Area 200, where they would be treated further. Off-gases produced in COINS would be sent to the GPCR unit in Area 400 for further treatment. Additional information on COINS, including several schematics, is provided in Foster Wheeler/Eco Logic/Kvaerner (2000).

#### **5.2.3.5.2 Munitions Access – Rockets**

As with the projectiles, the proposed design for munitions access for rockets incorporates many of the units and processes used in the baseline reverse assembly processes (see Appendix E of Volume 1 for details). Units and processes include reverse assembly machines, material handling conveyors, robotic loaders and handlers, auxiliary systems, and facilities and support systems. Some of these units have been slightly modified from the baseline process, but the basic unit and operations have been retained. The major differences, as compared with the baseline process and the process for projectiles, are summarized below.

Rockets would also be processed through the Area 100 dry and wet areas, as described above. However, a MRSM would be used to shear the rocket. In the modified system, the same procedures as applied in the baseline RSM would be used, except in a different order. The modified RDS punches, drains, and washes out the rockets. One rocket shear station (RSS) shears the fuzes, and another RSS then shears the rocket body into sections. A tube cutter cuts the shipping and firing tube and the fin assembly is unscrewed from the rocket motor to access the propellant grain. The M28 propellant grain is then pulled out of the motor case in its entirety and size-reduced with a grinder into a slurry. Slurried propellant material from the rockets would be transferred to a number of holding tanks for feed to neutralization (Area 200). Agent and spray wash water would be transferred to a buffer area similar to the baseline TOX. The sheared rocket parts (fuze, burster, and igniter) would be treated in the COINS as described above.

### 5.2.3.5.3 Agent Treatment

Agent treatment would be conducted in Area 200 in a treatment train separate from treatment of energetics. Nerve agent would be neutralized by reacting with NaOH (20% solution). Mustard agent would be neutralized first with water and then with NaOH solution. This dual treatment process for mustard agent would prevent the formation of undesirable vinyl compounds that could be formed if the mustard agent were treated with just water. Testing would confirm total neutralization. If testing detects residual agent, additional time would be allowed for agent treatment. Once the reaction is completed, treated hydrolysate would be pumped to surge tanks in Area 300, where the hydrolysate would await further treatment by TW-SCWO. Additional NaOH would be added while the hydrolysate is in these surge tanks, to maintain the appropriate pH. This eliminates the potential for agent reformation. All neutralization in the Area 200 reactors would be conducted under a nitrogen blanket. Nitrogen would be vented to Area 400 for treatment using GPCR.

Agent hydrolysate would be further treated by using TW-SCWO to destroy Schedule 2 and other organic compounds. The TW-SCWO system is designed to oxidize remaining organic materials in hydrolysates, including CWC Schedule 2 compounds, to water, CO<sub>2</sub>, and inorganic salts. The TW-SCWO system is similar to the solid-wall SCWO system discussed in Section 5.2.1.5, except that the unit incorporates a TW design. The TW is designed to place a layer of deionized water on the reactor's inner wall as a means of limiting corrosion and reducing the generation and buildup of salts and other solids that the technology provider claims can clog conventional systems. TW-SCWO also differs from the solid-wall unit in that the TW-SCWO can treat agent and energetic hydrolysates simultaneously.

After establishing system pressure, the system would initially be heated by startup water passed through a preheater. When the preheater temperature reaches approximately 1,100 °F (593 °C), startup fuel and oxygen would be pumped to the reactor to initiate the oxidation reaction. With ignition achieved, the startup fuel and startup water would be decreased (but not stopped), while the hydrolysate feed, diluent water, kerosene spike (auxiliary fuel), caustic, and oxygen would be introduced to the reactor. The use of auxiliary fuel would minimize operational fluctuations resulting from incoming hydrolysate variability. The caustic solution would be used to neutralize any acidic species that may form during the oxidation reaction. Two TW-SCWO reactors would be operated in parallel.

Near the exit of the reactor, water at 60 °F (15 °C) would be injected to rapidly quench the effluent to 600 °F (315 °C), causing most precipitated salts exiting the reactor to redissolve. After this, the effluent would pass through a back-pressure regulator valve to reduce system pressure before entering a knockout drum. Hot effluent liquid and vapors would be separated in the knockout drum, which includes a scrubber to remove particulate solids from the vapor. The hot vapors would flow to an effluent cooler where they would be cooled to 120°F (49°C). The cooled effluent would then flow to a flashed gas separator where the vapor fraction (flue gas) would be separated and filtered through carbon filters and would be vented to the atmosphere. The flue gas would be continually monitored for CO, CO<sub>2</sub>, nitrogen oxides (NO<sub>x</sub>), N<sub>2</sub>O, and O<sub>2</sub>.

Effluent would be analyzed for the presence of residual organics, and if it meets total organic carbon (TOC) specifications, it would be pumped to an evaporator/crystallizer system where water would be recovered and subsequently reused. If the effluent does not meet TOC requirements, it would be reintroduced into the TW-SCWO unit. Crystallized solids would be sent to a bin. If determined to be hazardous waste, the salts would be treated, as necessary, and disposed of as hazardous waste. As indicated previously, these salts may be delisted from being hazardous waste.

#### **5.2.3.5.4 Energetics Treatment**

Energetics treatment would be conducted in Area 200 in two separate treatment trains. One treatment train would be used for M28 propellant and the other would be used for all other energetics, including energetic material from bursters and fuzes. The M28 propellant would be neutralized after it was size-reduced with a grinder. The other energetic materials would be partially hydrolyzed in the COINS prior to bulk neutralization. As with nerve agent, neutralization would be conducted by reacting with NaOH (20% solution). Energetic material deactivation would be monitored by high-pressure liquid chromatography (HPLC). All other energetic treatment operations in Area 200 would be identical to those used for agent.

Following energetics neutralization, the energetics hydrolysate would be further treated in the TW-SCWO unit. Treatment there would be identical to that for agent hydrolysate.

#### **5.2.3.5.5 Metal Parts and Dunnage Treatment and Process Off-Gas Treatment**

Metal parts from Area 100 (projectile bodies), residual solids from COINS, and all dunnage would be treated in Area 400. Area 400 would also be used to treat process gases from other units that are part of this technology system, except for gases from the TW-SCWO unit. Area 400 would house the GPCR operation. In addition to the GPCR unit, the process would consist of a preheater unit for incoming process gases and a TRBP for 5X treatment of metal parts and dunnage. Gases from the TRBP would flow directly to the GPCR unit. In addition, the process includes a multistage system for gas scrubbing to remove inorganic contaminants and light hydrocarbons. The scrubber system would result in a process stream containing CH<sub>4</sub> and other hydrocarbons; this stream may be able to be used as fuel for a BIF.<sup>47</sup> Area 400 would also contain a product gas compression and storage unit.

Process gases from other units that are part of this technology system (except TW-SCWO), including recycled gases from the GPCR product gas compression and storage unit, would go to the GPCR preheater. There the gases would be preheated prior to processing in the GPCR unit.

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<sup>47</sup> It is unclear whether the product gas would meet BIF acceptance criteria (40 CFR, Part 266, Subpart H).



The TRBP is a device used to heat metal parts and dunnage, thereby volatilizing organic materials from these solids. The device also vaporizes organic materials such as cellulose and plastics. TRBPs have a capacity of 47 yd<sup>3</sup> (36 m<sup>3</sup>), and two of these devices are designed to operate in parallel. Each TRBP would operate in batch mode, for dunnage, and have 3 trays capable of holding 15 waste-bearing drums for a maximum weight of 11,023 lb (5,000 kg) for each batch treated. Air would be purged from the device using nitrogen. Then preheated hydrogen and superheated steam would be injected into each tray of the unit at a temperature of 1,382°F (750°C), through individual flexible hoses. The TRBPs would operate in a batch cycle from 32 to 48 hours, depending on the agent and campaign. Gases would then be swept from the TRBP and into the GPCR unit by a preheated hydrogen sparging stream. Toward the end of the 32- to 48-hour period, the TRBP would be heated up to a temperature in excess of 1,112°F (600°C) for 30 minutes or more to help ensure that a 5X condition has been obtained. Finally, the TRBP would be cooled and purged with nitrogen and steam to end the cycle. Remaining 5X solids would be removed and new solids would be loaded; removal and loading would take place through separate doors to prevent cross-contamination.

The GPCR reactor is designed to heat incoming waste streams and chemically reduce organic contaminants. Incoming streams would include preheated hydrogen, superheated steam, Area 100 and 200 off-gases, and volatilized waste from the TRBPs. These streams would be mixed in static mixers and would enter the unit at a temperature of 1,202 to 1,382°F (374 to 750°C). Residence time for incoming streams is between 2.5 and 10 seconds. The hydrogen and steam would react with the organic contaminants to produce HCl, HF, phosphorous oxides, H<sub>2</sub>S, and CH<sub>4</sub>. A secondary steam reforming reaction would produce CO, CO<sub>2</sub>, and H.

The GPCR unit also includes a gas scrubbing, water treatment, and compressing/storage system. The reduced gas from the GPCR unit would be processed through a series of scrubbers where caustic neutralizes acid gases. Inorganic salts would be precipitated from solution and filtered from the effluent. Naphthalene and solid particulates would be removed before the gas, which has now been cooled to near ambient conditions, goes to compressors. The gas compressors consist of a series of coolers for liquid separation. Liquid and gas would be stored in product gas storage tanks where the product would be tested to ensure complete treatment. The product gas is intended for reuse as supplemental fuel in the Area 400 process burners or Area 500 support services (heating) boiler. In the event that any gas fails to meet treatment criteria, it can be reprocessed in the GPCR unit. A final level of emission control redundancy would be provided by use of a catalytic converter. This would ensure that all of the fuel gas and product gas combusted in the process would be fully converted to CO<sub>2</sub> and water.

#### **5.2.3.5.6 Effluent Management and Pollution Controls**

The effluent management and pollution control systems used in neutralization/GPCR/TW-SCWO would be similar to systems used in the baseline incineration plant. These systems would be independent of agent and munition type. Elements of the system are described below.

The plant ventilation system is designed with cascading air flow from areas of less contamination potential to areas with more contamination potential. The ventilation system permits room air-change frequencies consistent with area-level designations<sup>48</sup> for normal as well as anticipated maintenance activities. Plant ventilation flow would be collected in the main plenum and directed to a bank of carbon filters. Two HEPA filters would also be used in series to remove particulates from the air streams. From here, the air would be filtered and monitored, passed through induction draft fans, and exhausted to the stack and the atmosphere. This system would be nearly identical to the baseline system.

The decontamination fluid supply system and spent decontamination fluid collection system would be the same as those used in the baseline system. Decontamination fluid would be supplied to most rooms in the main plant area, and spent decontamination fluid would be collected in sumps that would be monitored and controlled. The spent decontamination fluid would be transferred to the hydrolysis treatment area (Area 200), where it may be mixed with additional decontamination solution to ensure complete destruction of agent.

The DPE-supplied air and personnel support system would include maintenance air locks, donning/doffing support equipment, and facilities identical to baseline.

Rather than the baseline BRA, the evaporator/crystallizer would be used. This system is similar to the BRA unit used in the baseline system except that it would be modified to handle brine salts from the TW-SCWO process and water recovery by condensation for reuse in the plant. The evaporator/crystallizer would include equipment for effluent evaporation. If classified as hazardous waste, dried salts would be treated as necessary and disposed of in a hazardous waste landfill. Dried salts may also be delisted, as indicated previously.

The TRBP portion of the GPCR unit would result in treated metals and solids, which the TRBP is intended to treat to a 5X condition. While metals may be recycled, treated solids would be treated further, if necessary, and disposed of in a solid or hazardous waste landfill in compliance with regulatory requirements.

The plant instrument air and steam supply systems would be similar to those employed in the baseline system.

Control rooms would be the same as those used in the baseline system, with changes as needed to accommodate the new systems and equipment.

The process for handling munitions from storage to the unpack area would be similar to that used in the baseline system.

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<sup>48</sup> Level A, B, C, D, or E indicates the potential for contamination; Level A is the highest, and E is the lowest.

Personnel support, monitoring systems, and analytical laboratories would be similar to those used in the baseline system.

As indicated previously, elements of the baseline incineration process are included in the overview of the baseline and ACWA system technologies provided in Volume 1 of this TRD (see Section 1.4). In addition, the baseline incineration process is described in Appendix E of Volume 1.

#### **5.2.3.6 Common Elements – Other Systems**

The neutralization/GPCR/TW-SCWO process has several elements that are identical or nearly identical to other systems. Commonalities with other applicable technology systems include the following:

- The munitions access system used for neutralization/GPCR/TW-SCWO employs much of the baseline reverse assembly system, as do most of the other ACWA systems,
- Neutralization/GPCR/TW-SCWO employs essentially the same process as neutralization/SCWO and neutralization/biotreatment for neutralization as a primary treatment for chemical agents and energetics, and
- SCWO and TW-SCWO are comparable processes since they both involve oxidation of organics at supercritical conditions. Different ancillary equipment would be required for each type of SCWO unit, however.

Facility structure; ventilation; decontamination fluid supply; personnel support; pollution abatement; water, air, and steam supply systems; control rooms; monitoring systems; and laboratory support would be identical or nearly identical to the baseline system.

### **5.2.4 ELECTROCHEMICAL OXIDATION**

The electrochemical oxidation technology system uses modified baseline reverse assembly to access agents and energetics. Agents and energetics are then mineralized with an electrochemical oxidation process that uses silver nitrate ( $\text{AgNO}_3$ ) in concentrated nitric acid ( $\text{HNO}_3$ ). Hardware and solids are thermally decontaminated.

The technology provider refers to its process as the SILVER II process. This neutralization process takes place in a standard industrial electrochemical cell and relies on the

oxidizing capability of  $\text{Ag}^{2+}$  ions in a solution of  $\text{HNO}_3$ . The  $\text{Ag}^{2+}$  ions mineralize organics to  $\text{CO}_2$ , inorganic salts, water, and acids. Electrochemical oxidation differs from the other three technologies evaluated in this TRD in that no secondary treatment is needed to address Schedule 2 compounds.

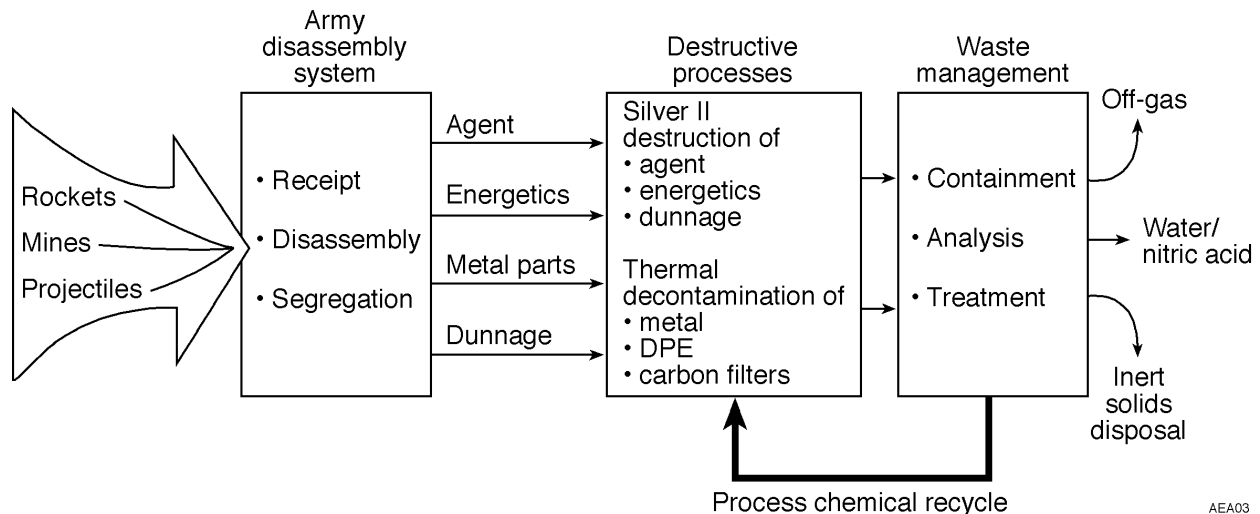
This technology is applicable to all ACW stored at BGAD, including ACW containing nerve or mustard agent, and it is reported as also being effective for energetics. The process for munitions access differs slightly for M55 rockets and M56 warheads, versus that for projectiles stored at BGAD. Following munitions access, treatment of agent and energetics from the various types of ACW is largely independent of munition type and agent fill.

SILVER II was proposed by AEA Technology/CH2MHILL. The following subsections provide a more detailed discussion of the technologies and processes involved in this system. The technology provider's technology demonstration report (AEA/CH2MHILL 2000) may be viewed for additional detail.

#### 5.2.4.1 Process Overview

Figure 5.17 provides an overview of the electrochemical oxidation process using SILVER II. As Figure 5.17 illustrates, the U.S. Army's baseline reverse assembly process would be used to disassemble ACW at BGAD. However, fluid-abrasive cutting and fluid-mining that employ water and grit would be used to access the rockets. Spent grit would be filtered from the water and sent to thermal treatment; the water would be reused for fluid-abrasive cutting. A rocket demilitarization machine (RDM) has replaced the baseline RSM. The RDM is a new machine that performs the same function as the existing RSM. The rocket processing begins with the automatic feeding of the rocket, contained in its firing tube, to the punch and drain station. The RDM would punch and drain rockets, and steam would be used to wash the agent reservoir. The agent would be drained and pumped to buffer storage tanks, the same as for projectiles and mortars. The rocket would then be fluid jet cut into three sections. The fuze, warhead, motor, shipping and firing tube, and fin assembly would then be separated. Bursters would be fluid-mined to remove the explosive charges. The M28 propellant grain would be pulled from the motor case in its entirety and size-reduced with a two-stage grinder into a slurry. The rocket parts and fiberglass shipping/firing tube would be transferred to thermal treatment. For projectiles, the baseline PMD process would be used to remove the explosive train. Projectile bursters would be fluid-mined to remove the explosive burster charge. A punch/drain/washout machine (PDWM) would access the agent cavity in projectiles, and agent would be drained using gravity. Steam would be used to wash the agent reservoir.

Fuzes and supplementary charges from all ACW at BGAD would be sent to a detonation chamber. The detonation chamber is a thermally initiated, contained detonation device that initiates the energetics by exposing them to heat.



**FIGURE 5.17 Overview of the AEA/CH2MHILL SILVER II Process for the Treatment of ACW at BGAD (Source: Adapted from NRC 1999)**

Slurried explosive material from the ACW (20% by weight) would be sent to a number of holding tanks for feed to the SILVER II reactor. Agent would be pumped to a buffer area similar to the baseline TOX holding system. Solid secondary wastes (i.e., dunnage) would be size-reduced using two-stage shredders. Metal components, including projectile bodies, would be thermally treated to a 5X<sup>49</sup> condition in a MPT, and dunnage would be thermally treated in a batch rotary treater (BRT). All process off-gases would pass through a catalytic oxidation unit and through carbon filters prior to release to the atmosphere.

Agents and energetics would be fed into separate SILVER II reactors. A 2-kW unit for agents and a 12-kW unit for energetics were used during demonstration testing. SILVER II is an aqueous electrochemical process that uses  $\text{AgNO}_3$  in concentrated  $\text{HNO}_3$ . An electrochemical cell is used to generate a reactive material ( $\text{Ag}^{2+}$ ) that readily oxidizes organic substrates. End products of this oxidation process are primarily  $\text{CO}_2$  and water. Elements present in the organic substrate, such as nitrogen, sulfur, or phosphorous, are oxidized to nitrate ions, sulfate ions, or phosphate ions. Silver compounds (e.g., chloride) would be recycled or recovered off-site, after which they may be returned to the process.

#### 5.2.4.2 History of Destructive Processes

The electrochemical oxidation process is a relatively new technology with respect to destruction of agent or energetics in the stockpile of ACW. The SILVER II process has yet to be

<sup>49</sup> The definition of 5X is provided in Volume 1 of this TRD (see Section 1.2.2.4).

used commercially for waste treatment, although a number of tests have been conducted on various materials. The type of electrochemical cell used in the SILVER II process is, however, used commercially in the chlor-alkali industry (NRC 1999).

Prior to the PMACWA demonstration, the largest pilot-scale tests for waste treatment have been conducted using a 4-kW cell consisting of a single anode-cathode pair. The most extensive tests have been conducted with spent tributyl phosphate dissolved in kerosene. These tests ran continuously for up to 14 days, and 40 gal (150 L) of feed material was destroyed. The electrochemical oxidation technology also has been successfully tested on 0.35 oz (10-g) batches of agent at a pilot plant in Porton Down, United Kingdom. The Porton Down unit is similar in design to the system being proposed for the ACWA program. It includes anolyte and catholyte feed circuits, an anolyte off-gas condenser, an NO<sub>x</sub> reformer system,<sup>50</sup> and a modified version of the off-gas treatment circuit, including a NaOH scrubber (NRC 1999).

Additional tests on VX have been conducted at Porton Down. The test involved a continuous run of six and a half days. At the end of the test, no agent residuals could be detected. The VX destruction efficiency was calculated at 99.99998%, in terms of organic carbon. With respect to TOC, the destruction efficiency was calculated at 88.7% (NRC 1999).

The NRC has expressed concerns over the electrochemical oxidation process, particularly in the case of scaling up to meet production schedules for the wide variety of ACW to be destroyed. The NRC expressed concern over the ability to maintain appropriate temperatures in a scaled-up system. The set point of the process is 194°F (90°C); because the process employs large amounts of electricity, there is a potential problem in controlling those temperatures. Another concern comes from the size of particles. In commercial production, particles are expected to be larger than those experienced in tests. According to the NRC (1999), larger particles tend to limit the feed rates. The NRC indicated that these concerns must be addressed in future tests, particularly when approaching commercial scale (NRC 1999). Demonstration testing, described below, was intended, in part, to address these concerns.

#### 5.2.4.3 Demonstration Testing<sup>51</sup>

As discussed for the other technology systems presented in this TRD, baseline reverse assembly, carbon filtration, and the brine reduction operation were not demonstrated as part of the demonstration test program for electrochemical oxidation. Other unit operations proposed for this technology were also not selected for demonstration. The following unit operations proposed

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<sup>50</sup> An NO<sub>x</sub> reformer is an add-on pollution control device designed to remove NO<sub>x</sub> after formation. The device uses water to form nitric acid.

<sup>51</sup> This material describes the Demo II PMACWA program and was based in part on PMACWA (2001a). Because demonstration testing was intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

for SILVER II were not selected for demonstration by the PMACWA for the reasons given below.

- Shredder (size reduction). This is common commercial equipment used for marginal size reduction of solid secondary wastes for feed to the BRT. Extensive size reduction capabilities were previously validated by the PMACWA as part of Demo I and EDS-I.
- RDM. The RDM is a new addition to the proposed full-scale process and was incorporated after Demo II was conducted (AEA/CH2MHILL 2000). The punch and drain stations are based on the existing baseline RSM.
- Cutting Station. The fluid-abrasive cutting and fluid-mining operations are substantially similar to the rocket-cutting and fluid-mining technology previously validated by the PMACWA as part of the neutralization/biotreatment technology (PMACWA 1999a,b).
- M28 Propellant Grinding. Several ACWA technologies require size reduction of M28 propellant. Therefore, the PMACWA elected to conduct a single design study (during EDSs) to address this requirement.
- PDWM. The PDWM for projectiles is a new addition to the proposed full-scale process and was incorporated after Demo II was conducted (AEA/CH2MHILL).
- Projectile Burster Washout. This operation is substantially similar to the burster washout technology previously validated by the PMACWA as part of the neutralization/biotreatment technology (PMACWA 1999a,b).
- Steam Spray Wash. Water spray washout of ton container vessels and steam washing of ton container tubing were demonstrated at the ECBC, Aberdeen Proving Ground, Maryland.
- Detonation Chamber. This device is a contained blast chamber and is a commercially available, indirect, electrically heated vessel.
- MPT and BRT. The MPT and BRT are similar to the MPT previously validated by the PMACWA as part of the neutralization/biotreatment technology (PMACWA 1999a,b).

- Catalytic Oxidation System. The catalytic oxidation system is commercially available; it is also similar to the CatOx previously validated by the PMACWA as part of the neutralization/biotreatment technology (PMACWA 1999a,b).
- Agent Impurities Removal System (AIRS) and Energetics Impurities Removal System (EIRS). These are new additions to the proposed full-scale process and were incorporated after Demo II was conducted (AEA/CH2MHILL 2000).

The reasons for selecting the electrochemical oxidation demonstration unit operations, testing objectives, and the significant deviations from the planned testing are discussed in the following subsections. Demonstrations with a 2-kW SILVER II unit (for agents) and a 12-kW SILVER II unit (for energetics) are discussed separately.

#### **5.2.4.3.1 2-kW SILVER II Unit (Agent)**

A 2-kW SILVER II unit was demonstrated to validate destruction of the agents contained in ACW and to correlate with the 12-kW SILVER II unit through testing with agent simulants. The 2-kW SILVER II unit was demonstrated at Building E3566 at the Edgewood Area of APG, Maryland. The demonstration system was an integrated unit consisting of the following:

- Feed System – The agent for each run is pumped from a steel container into two premix vessels for metering into the anolyte vessel at an appropriate rate, according to the destruction efficiency of the particular organic material.
- Electrochemical Process – The electrochemical cell contains titanium electrodes that are electroplated with platinum. It is designed to operate at a maximum current of 1,000 amps per electrode face; the power supply voltage is automatically varied to maintain the set current. The electrochemical cell consists of two cathodes flanking an anode. The electrodes are separated into anolyte and catholyte compartments by membranes made of a perfluoro ion-exchange polymer. The organic feed is metered into the anolyte vessel that contains 8-M  $\text{HNO}_3$  and 10%  $\text{AgNO}_3$ . Fluids from the anolyte circuit flow through the channels and are exposed to the anode in the cell. When the current is turned on, the  $\text{Ag}^{2+}$  ions generated oxidize the organic feed. Some  $\text{Ag}^+$  ions and water (as hydrated protons) pass through the electrochemical cell membrane and flow into the catholyte vessel, which contains 4-M  $\text{HNO}_3$ . The cathodic reaction reduces the  $\text{HNO}_3$  to  $\text{NO}_3$  and water in the catholyte vessel.



- **Particulate Removal and Treatment** – Silver chloride (AgCl) precipitates when chlorinated feeds (i.e., mustard) are exposed to HNO<sub>3</sub> and AgNO<sub>3</sub>. The particulate removal process is integrated into the electrochemical process unit; a hydrocyclone<sup>52</sup> on the anolyte circuit removes the AgCl before it reaches the electrochemical cell. The AgCl accumulates in a separate evaporator oven for 5X treatment. The vapor from the oven passes to a condenser, and the condensate is returned to the anolyte vessel. The AgCl is then removed as a solid cake for silver reclamation.
- **NO<sub>x</sub> Reformer Circuit** – The reactions with Ag<sup>2+</sup>, which occur in the anolyte circuit, release CO<sub>2</sub>, CO, and NO<sub>x</sub>. The reactions occurring in the catholyte circuit release NO<sub>x</sub>. Off-gas from both circuits passes through a condenser to remove some of the NO<sub>x</sub> vapors and then travels to the NO<sub>x</sub> reformer. Because of facility size restrictions, the 2-kW plant included an NO<sub>x</sub> reformer with a single column for absorption and distillation. As the gas travels up the column, water running down the column reacts with NO<sub>x</sub> in the gas to form dilute HNO<sub>3</sub>. The dilute HNO<sub>3</sub> is heated to evaporate water and to produce concentrated HNO<sub>3</sub>. The evaporated water is condensed and produces very dilute HNO<sub>3</sub>, which is recycled to the anolyte vessel or disposed of as waste. The concentrated HNO<sub>3</sub> is recycled to the catholyte vessel or can be used commercially.
- **Caustic Scrubber Circuit** – Off-gas from the NO<sub>x</sub> reformer is sent to the caustic scrubber tower to remove any residual NO<sub>x</sub> before release of the gas to the facility ventilation system.

Laboratory-scale testing of a SILVER II unit for agent has previously been performed with GB. Destruction of HT and VX has previously been tested at a scale similar to that of the demonstration unit. Characterization of gaseous, liquid, and solid effluents and verification of operating parameters were required during demonstration testing. The specific test objectives of this demonstration unit included the following:

- Validate the ability of the 2-kW SILVER II unit to achieve a DRE of 99.9999% for mustard, GB, and VX agents.
- Determine the impact of operations on materials of construction to be used in a full-scale system.
- Demonstrate the operation and performance of the following key process components for future scale-up:

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<sup>52</sup> A hydrocyclone, also known as a water cyclone, is a device used to separate fluids with different densities.

- Instrumentation, valves, pumps, etc.
- Hydrocyclone (to determine its ability to deal with solids in the anolyte circuit).
- Electrochemical cell (electrodes and membranes).
- Develop operational data to facilitate comparison of the 2-kW SILVER II unit with the 12-kW SILVER II unit for use in scaling up SILVER II.
- Characterize silver-bearing residuals. Determine potential silver recovery and determine disposal options (via characterization) for residuals from silver recovery operation (mustard only).
- Characterize gas, liquid, and solid process streams from SILVER II for selected chemical constituents and physical parameters, and for the presence or absence of hazardous, toxic, agent, agent simulant, and Schedule 2 compounds.

Significant deviations from the planned demonstration testing included the following:

- Reduction in the VX validation run quantity (from 22 to 9 lb [10 to 4 kg]) and duration because of schedule constraints, and
- Elimination of the chloroethyl ethyl sulfide (CEES) validation run because of difficulty in obtaining CEES in the quantity needed and schedule constraints.

#### **5.2.4.3.2 12-kW SILVER II Unit (Energetics)**

A 12-kW SILVER II unit was demonstrated to validate destruction of the energetics contained in ACW and to correlate with the 2-kW SILVER II unit through testing with simulants. The 12-kW SILVER II unit was demonstrated at the Fire Safety Test Enclosure at the Aberdeen Test Center, Aberdeen Area of APG, Maryland. The demonstration system was an integrated unit consisting of the following:

- Feed System – The energetics feed system is designed to maintain the energetics material in a 20% slurry with water by storing it in a continuously mixed feed vessel. Two forms of agitation ensure that the energetics remain in the slurry: an air-driven mixer and a recirculation loop. The energetics slurry is fed to the anolyte vessel by bleeding off a slipstream from the recirculation loop.

- SILVER II System – The SILVER II system of the 12-kW unit is the same as that for the 2-kW SILVER II unit, except that it does not have a particulate removal and treatment system.<sup>53</sup> It does, however, have a complete NO<sub>x</sub> reformer circuit that includes separate absorption and distillation columns. As gas travels up the absorption column, water running down the column reacts with the NO<sub>x</sub> in the gas to form dilute HNO<sub>3</sub>. The dilute HNO<sub>3</sub> leaves the bottom of the absorption column and enters the distillation column where it is heated to evaporate water and produce concentrated HNO<sub>3</sub>.

Energetics testing in a laboratory-scale SILVER II unit was previously performed with RDX, TNT, tetryl, and a double-base propellant similar to M28. Characterization of gaseous, liquid, and solid effluents and verification of operating parameters were required. The specific test objectives of this demonstration unit included the following:

- Validate the ability of the 12-kW SILVER II unit to achieve a DRE of 99.999% for Composition B (RDX and TNT), tetrytol (tetryl and TNT), and M28 propellant.
- Validate the ability of the 12-kW SILVER II unit to achieve a DRE of 99.9999% for dimethyl methylphosphonate, a VX/GB simulant.
- Determine the impact of operations on materials of construction to be used in a full-scale system.
- Demonstrate the operation and performance of the following key process components for future scale-up:
  - Instrumentation, valves, pumps, etc.
  - Electrochemical cell (electrodes and membranes).
  - Full-height NO<sub>x</sub> reformer/silver recovery boiler (ability to maintain H<sub>2</sub>O balance).
  - Off-gas scrubber operating in conjunction with the NO<sub>x</sub> reformer.

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<sup>53</sup> No chlorinated feeds were processed in this unit; thus, the particulate removal and treatment system was removed from the unit.

- Develop operational data to facilitate comparison of the SILVER II 2-kW agent system with the 12-kW SILVER II energetics system for use in scaling up the SILVER II agent system.
- Demonstrate the ability or inability to recycle, reuse, or dispose of  $\text{HNO}_3$ .
- Characterize gas, liquid, and solid process streams of SILVER II for selected chemical constituents and physical parameters and for the presence or absence of hazardous and toxic compounds.

Significant deviations from the planned demonstration testing included the following:

- Elimination of the CEES validation run because of difficulty in obtaining CEES in the quantity required and schedule constraints,
- Reduction of the quantity of M28 propellant (from 440 to 308 lb [200 to 140 kg]) because of schedule constraints, and
- Elimination of planned Composition B testing because of schedule constraints.

#### **5.2.4.3.3 Summary of Demonstration Testing**

In summary, demonstration testing during Demo II was not as extensive as testing during Demo I because of the similarity of some of the unit processes and technologies. The 2-kW and 12-kW SILVER II systems were each evaluated during the demonstration. Schedule constraints, however, prevented the PMACWA from completing demonstration testing with VX, some of the energetics, and CEES simulant. Nevertheless, the PMACWA has determined that SILVER II is effective in destroying agents and propellant at the targeted levels. However, the curtailed tetrytol demonstration and lack of any demonstration data for Composition B prohibits the complete validation of the process. The technology includes operations to effectively process metal parts and dunnage. Although Composition B has not been demonstrated, greater than 99.999% destruction of the constituents of Composition B and tetrytol in laboratory experiments indicates the likely effectiveness with these energetic compounds (PMACWA 2001b). The PMACWA reviews the quality of the data generated during demonstration testing in PMACWA (2001f).

On the basis of demonstration testing, the technology provider plans some substantive changes to the electrochemical oxidation SILVER II technology. One concern in regard to process operability is the treatment of burster energetics (tetrytol and Composition B) in the SILVER II system. A limitation of SILVER II was discovered when tetrytol was fed to the

12-kW SILVER II demonstration unit at the originally planned feed rates (AEA/CH2MHILL 2000). Because SILVER II had problems decomposing an intermediate product, material began to precipitate within the anolyte circuit. Consequently, the system had to be shut down to clear the lines. The technology provider's solution to the precipitation problem was to add a hydrocyclone and a high-speed mixer in the anolyte circuit (AEA/CH2MHILL 2000). According to PMACWA (2001b), there was also a buildup of organics in the catholyte. The catholyte circuit was periodically drained, and the drained catholyte solutions were never reintroduced into the anolyte. Thus, it is possible that the intermediate product that was concentrating within the catholyte was only partially treated. A catholyte-to-anolyte recycle stream is proposed to reduce the buildup of organics within the catholyte.

In addition to the above, the technology provider has added a RDM for munitions access of rockets and a PDWM for munitions access for projectiles. An agent impurities removal system (AIRS) and energetics impurities removal system (EIRS) have also been added to the agent and energetic SILVER II units. These are new additions to the proposed full-scale process that were incorporated after Demo II was conducted (AEA/CH2MHILL 2000).

Upon incorporation of these changes, the technology provider believes that feed rates can be increased to the originally planned values. While these proposed improvements all have merit, optimization studies may be required (PMACWA 2001b). Additional details of the results of demonstration testing may be obtained from AEA/CH2MHILL (2000) and PMACWA (2001b,c).

#### 5.2.4.4 Engineering Design Studies<sup>54</sup>

During the demonstration testing described above, electrochemical oxidation was demonstrated to be a viable technology system for destruction of ACW, in accordance with the requirements of the PMACWA. However, the PMACWA determined that further studies would be necessary in preparation for full-scale pilot design and permitting. Therefore, EDSs will be conducted to provide this information. EDS-II objectives were as follows:

- Provide information for the full-scale facility with respect to total life-cycle cost, schedule, and safety;
- Support the EIS and permit application preparation under RCRA; and

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<sup>54</sup> This material describes EDSs for the technologies evaluated in the Demo II PMACWA program and was derived from PMACWA (2001a). EDSs for Demo II technologies are designated EDS-II. Because demonstration testing was intended to apply to a variety of ACW from all storage sites, this section does not discriminate with regard to munition type and storage installation.

- Support preparation of a RFP for a full-scale pilot plant facility.

As of the preparation of this TRD, EDS-II plans were not firm and are likely to change as the program proceeds. However, EDSs for this technology are expected to be ongoing at about the same time that this TRD is published. According to PMACWA (2001a), EDS-II, as planned, included further investigation of the following issues associated with electrochemical oxidation:

- Modifications to 12-kW plant energetics feed and ancillary systems;
- 500-hour runs of agent simulant and Composition B/M28 propellant with the 12-kW plant;
- Laboratory-scale testing on cell membrane life and feeds containing fluoride;
- Testing of hydrocyclones, high shearing mixing, and organic transfer; and
- Paper studies on projectile burster wash and energetic slurry concentration.

Table 5.4 provides further information on planned EDS-II activities for electrochemical oxidation. Figure 5.18 is an overview of the electrochemical process and shows unit operations that may be further evaluated during EDS-II. Planned evaluations of unit operations are independent of munition type or agent fill.

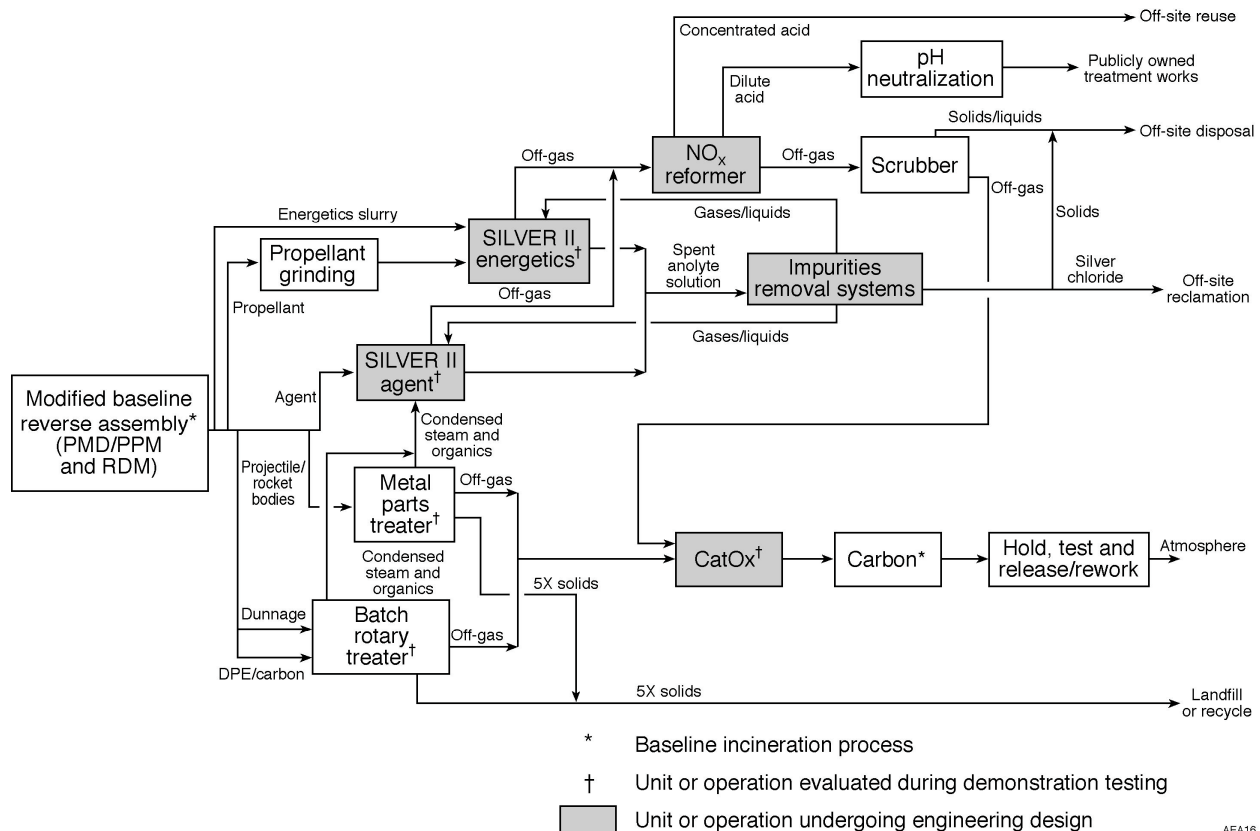
#### **5.2.4.5 Detailed Process Description**

This section presents a detailed process description for electrochemical oxidation, as applied to the ACW stored at BGAD, on the basis of demonstration testing results. The equipment used in a pilot-scale facility may vary in nomenclature and design from that described here, depending on the system selected and system requirements.

Figure 5.19 shows the entire process for electrochemical treatment of ACW at BGAD. Munitions access would use modified baseline reverse assembly. Fuzes, boosters, and supplementary charges would be treated in a detonation chamber. Metal parts from the detonation chamber, munitions hardware, dunnage, and other solid wastes would be thermally decontaminated to a 5X condition in either the MPT, an inductively heated vessel with a superheated steam reactive environment, or the BRT, a rotary version of the MPT with a structure similar to that of the baseline DFS. Steam would be condensed from the MPT or BRT and treated in the SILVER II process. Agents would be drained from the ACW, and energetics would be removed and slurried.

**TABLE 5.4 Potential Further Studies under Engineering Design Study-II**

Test Elements	Objectives
Modifications to 12-kW and ancillary systems	Provide extended, reliable feed of energetics.
Anolyte and catholyte circuits	Implement and demonstrate selected improvements to vessels, piping heating, controls, mixing, and separation.
Cell membrane life	Confirm membrane life over an extended period of operation.
Feedstock containing fluoride	Confirm transport of fluoride within the process and investigate methods to mitigate impact on materials of construction.
Hydrocyclone testing	Optimize design for removal of process intermediates.
High shear mixer testing	Investigate mixing performance for optimal destruction of organics and overall process performance.
Organic transfer across cell membrane	Investigate migration of organic species across cell membranes for long-term system performance.
Projectile burster washout	Confirm proof of concept and identify design parameters for projectile burster washout.
Energetic slurry concentration safety	Assemble and summarize available information to guide energetic slurry management.



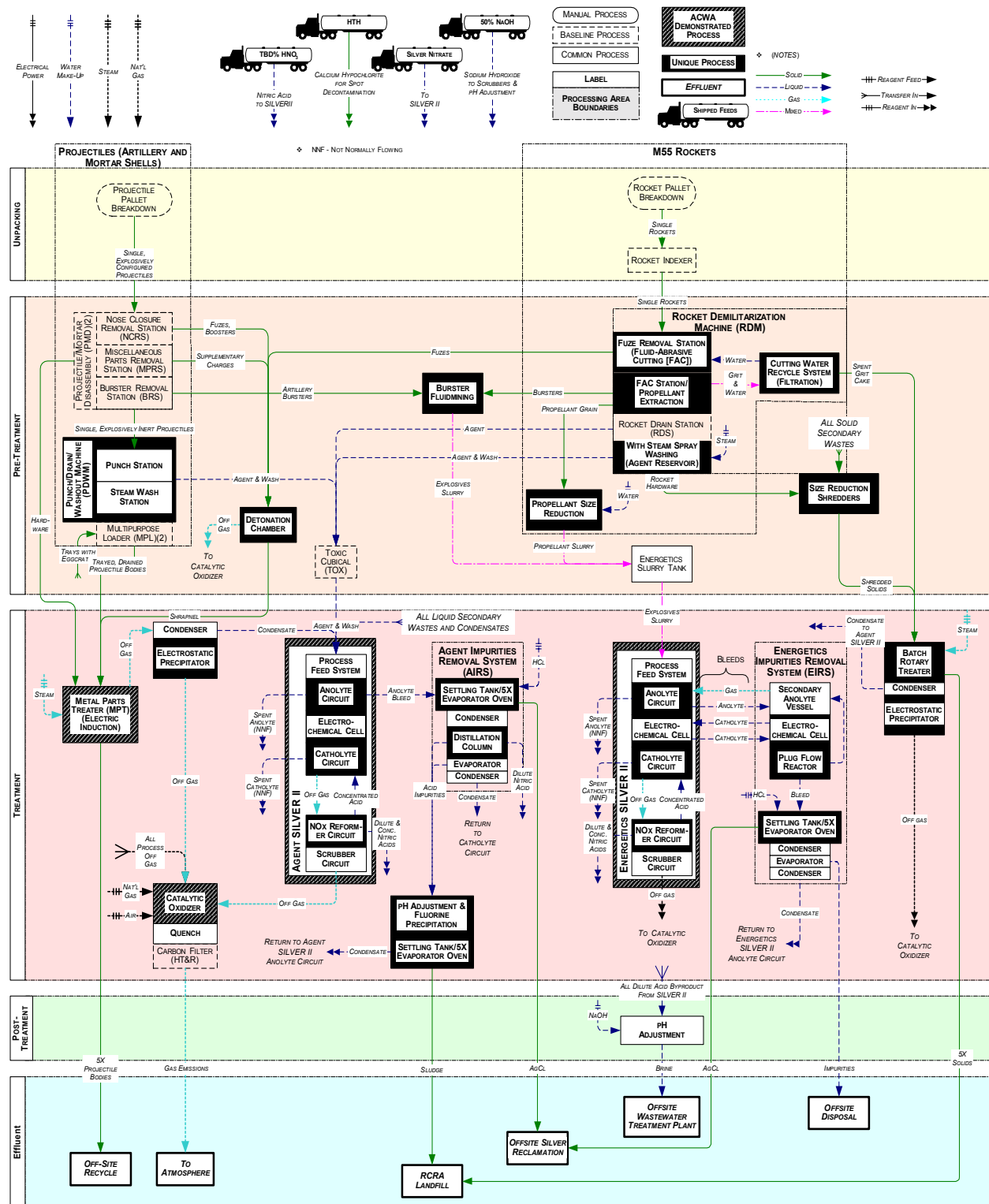
**FIGURE 5.18 Flow Diagram of Electrochemical Oxidation SILVER II Process (AEA/CH2MHILL System) Showing Units or Operations Undergoing Engineering Design (Source: Adapted from PMACWA 2001a)**

Drained agents and slurried energetics would be treated in separate SILVER II processes. These processes mineralize the agent and energetics with electrochemical oxidation facilitated by  $\text{Ag}^{2+}$  ions. The SILVER II process is supported by an agent impurities removal system (AIRS) and an energetic impurities removal systems (EIRS). These units each generate process solids that would be treated further, as necessary, and that would be disposed of off-site in a RCRA hazardous waste landfill. Silver would be reclaimed off-site, and  $\text{HNO}_3$  would be generated for reuse in the process. Dilute acid by-product from SILVER II is intended for treatment in an on- or off-site wastewater treatment plant.

All process off-gas would be mixed with air and catalytically converted by the catalytic oxidizer technology, followed by carbon filtration and release to the atmosphere. Treated muniton bodies (5X condition) would be commercially recycled.<sup>55</sup> Treated solid wastes (5X condition) would be treated further, as necessary, and placed in a landfill as RCRA

<sup>55</sup> Solids treated to a 5X condition to remove residual agent may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste as defined in 40 CFR 260.21 – 260.24.





AEA04

**FIGURE 5.19 Entire Flow Diagram of Electrochemical Oxidation Using SILVER II Process at BGAD (Source: PMACWA 2001b)**

hazardous waste or disposed of as nonhazardous waste in accordance with regulatory requirements.<sup>56</sup>

Short descriptions of each of the unit processes included in the electrochemical oxidation technology system are provided below. Following munitions access, the process for treating agents and energetics would be largely independent of munition type and agent fill.

#### **5.2.4.5.1 Munitions Access – General**

The SILVER II process uses modified baseline reverse assembly and fluid accessing (fluid-abrasive cutting and fluid-mining using water) for ACW pretreatment. Spent grit would be filtered from the water and sent to thermal treatment; the water would be reused for fluid-abrasive cutting. Slurried explosive material from the ACW (20% by weight) would be sent to a number of holding tanks for feed to the SILVER II reactor circuit. Agent would be pumped to a buffer area similar to the baseline TOX system. Solid secondary wastes (e.g., dunnage) would be size-reduced using two-stage shredders. Metal parts and dunnage would be treated thermally to a 5X condition in a manner similar to methods used in other technologies. Details for handling of projectiles and rockets are presented in the following subsections.

#### **5.2.4.5.2 Munitions Access – Projectiles and Mortars**

As indicated in Section 5.2.4.5.1, projectiles and mortars would be disassembled in the PMD. They would be received in the unpack area and loaded into the existing feed equipment for transportation into the ECR. Two identical disassembly equipment lines are planned. The PMD would remove the nose closure or fuze, burster, supplemental charge, and miscellaneous parts. Fuzes and supplemental charges would be conveyed to the detonation chamber for deactivation. The detonation chamber is a thermally initiated, contained detonation device that accesses explosive components (i.e., fuzes/boosters, supplementary charges, and igniters) by exposing them to heat. Burstern would be extracted and conveyed to a stand-alone burster washout machine to fluid jet out the burster, with conventional fluid jet technology. This would result in an energetic slurry with a nominal maximum particle size of 0.02 in. (0.5 m) and a slurry concentration not to exceed 20 percent by weight.

The burster slurry would feed directly to SILVER II, though some quantity may also be pumped to the energetics buffer storage tank for subsequent processing in SILVER II. The buffer

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<sup>56</sup> While these solid wastes are not known to contain chemical agent, they may be defined as hazardous waste if they exhibit any of the characteristics of hazardous waste as defined in 40 CFR 260.21 – 260.24. These solids may contain heavy metals and exhibit the RCRA toxicity characteristic (40 CFR 261.24). In Kentucky, the solids may be regulated as listed hazardous wastes because of their association with chemical agent. These solids may be delisted and not considered hazardous waste if regulatory delisting criteria are met.

storage would be designed to allow the SILVER II plant to operate continuously (if needed). The disassembly plant would operate 12 hours per day. The maximum quantity of energetic would depend on the energetic being destroyed.<sup>57</sup>

A PDWM would access the agent cavity in projectiles and mortars, and drain and wash them. The punch and drain machine would extract the liquid agent. Two 1-in. (2.5-cm) holes, 180° apart at each end, would be punched through the sidewall into the agent reservoir of the projectile. Following draining of the agent, the projectiles would be steamed out to maximize the removal of residual or gelled agent. The agent would be pumped to the agent buffer storage tank and then to SILVER II. The storage tank would be designed to operate continuously (if needed). The storage capacity would be 150 gal (568 L).

Projectile/mortar casings from the punch and drain machine would be placed in a metal carrier tray and conveyed to the MPT for 5X treatment. Burster wells, nose closures, and fragments from the detonation chamber would all be treated in the MPT to achieve 5X decontamination.

#### **5.2.4.5.3 Munitions Access – M55 Rockets**

M55 rockets would be transported to the unpack area and loaded into the rocket loading device in the same manner as the existing baseline system. Two identical parallel rocket disassembly lines, each contained in separate ECRS would be used. The individual rocket would be conveyed through the air lock and into the ECR, which contains the RDM. The RDM is a new machine that performs the same function as the existing RSM. The rocket processing begins with the automatic feeding of the rocket, contained in its firing tube, to the punch and drain station. This is based on the existing punch and drain process, but has the addition of a final steam-out to remove residual agent. The agent would be drained and pumped to buffer storage tanks, the same as for the projectiles. The rocket then would be fluid jet cut into three sections. A fuze cut would be made to separate the fuze and expose the burster section. A tail cut would be made to separate the tail section and expose the bottom end of the propellant grain for subsequent extraction. Disposition of individual rocket components would be as follows:

- The fuze sections would be deposited in mesh containers and conveyed to the detonation chamber for destruction.
- The warhead section would be conveyed to the burster washout station where the burster would be washed out. This would result in an energetic slurry with a nominal maximum particle size of 0.02 in. (0.5 mm) and a slurry concentration not to exceed 20% by weight. The slurry would feed directly to

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<sup>57</sup> Storage capacity, spread across a number of tanks, will be up to 1,500 pounds of M28 rocket propellant, or significantly lower quantities of high explosive.

SILVER II, though some quantity may also be pumped to the energetics storage tank as discussed previously. The warhead section would then be deposited in a container tray and conveyed to the metal parts treatment process. The container tray typically holds 10 to 15 warhead sections.

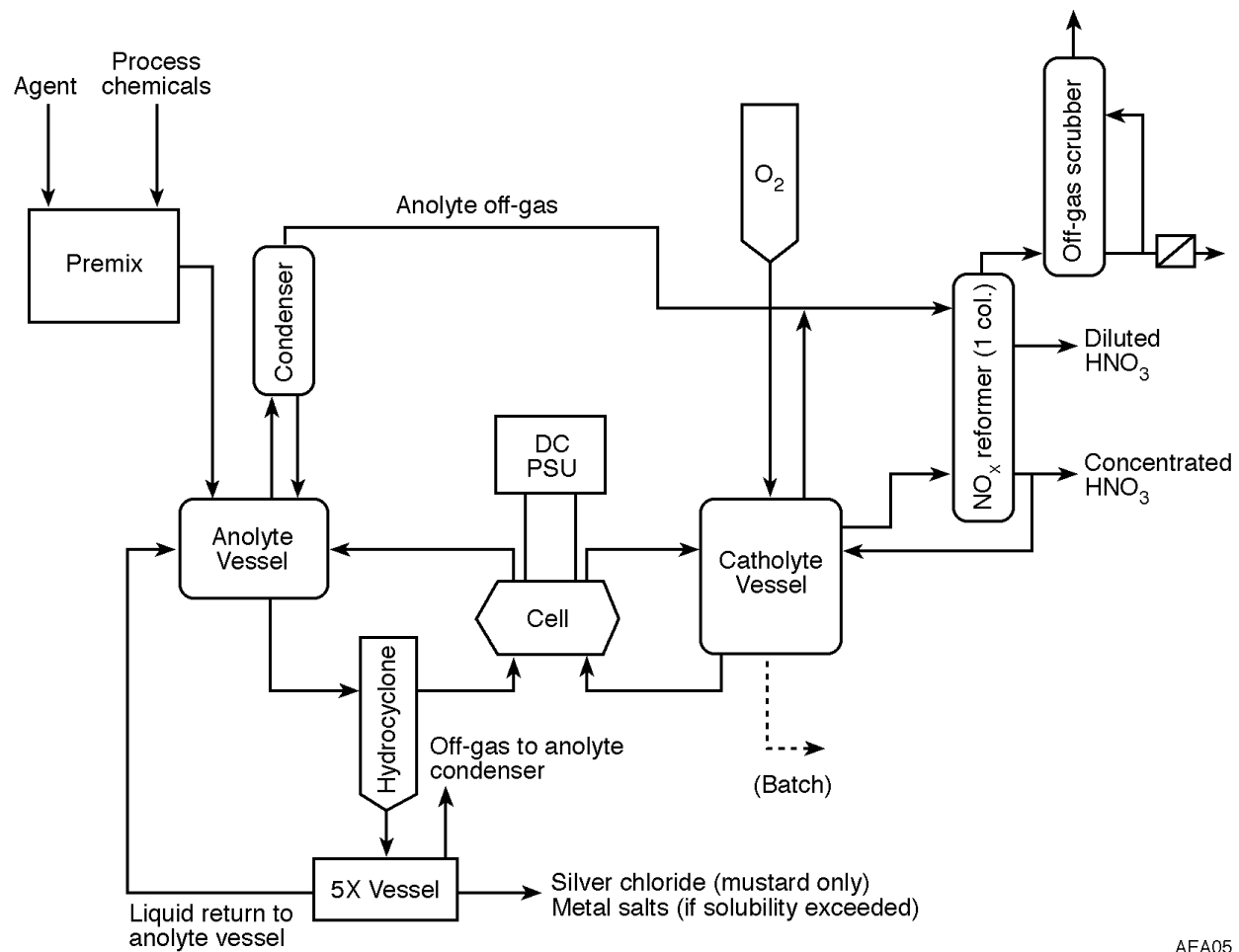
- The rocket motor and tail section would be conveyed to the propellant removal station, where the M28 propellant grain would be pulled from the motor casing. The motor and tail section would be deposited in a container tray for subsequent metal parts washing. The propellant would be conveyed to the propellant size reduction station.
- Fiberglass firing tube sections would be deposited in a container tray and conveyed to the dunnage treatment process for thermal treatment to a 5X condition.

#### 5.2.4.5.4 Agent and Energetics Treatment

Agents and energetics would be destroyed using electrochemical oxidation in the SILVER II process. SILVER II is a mediated electrochemical oxidation using  $\text{Ag}^{2+}$  ions in aqueous  $\text{HNO}_3$  (formed by an electrochemical cell) that is circulated through CSTRs (anolyte and catholyte circuits). The electrochemical oxidation process uses essentially the same system for destroying both agent and energetics. During demonstration testing, agent was destroyed in a 2-kW electrochemical cell (Figure 5.20), while energetics were destroyed in a 12-kW cell (Figure 5.21). Drained agent, along with liquids condensed from the BRT and MPT (see below), would be destroyed in the agent SILVER II unit. Propellant and high explosives (from bursters) would be destroyed in the energetics SILVER II unit. It is probable that the same kW systems for agent and energetics would be used in the pilot-scale design.

The SILVER II unit would consist of a feed system, an anolyte circuit, and a catholyte circuit integrated with a  $\text{NO}_x$  reformer and agent and energetics impurities removal systems (AIRS and EIRS, respectively). It is operated at a temperature of 190°F (90°C) and near atmospheric pressure. SILVER II, originally a semicontinuous batch process, is made a continuous process through a “bleed” to impurities removal systems. The AIRS and EIRS are used for removal of impurities.

In these removal systems, a purge system would be withdrawn from the anolyte reservoir. The rate is designed to limit the concentration of impurities in the anolyte to ~ 1M phosphate and sulfate in order to avoid precipitation of their silver salts. Other impurities of lower flux (such as iron, aluminum, etc.) would be maintained at significantly lower concentrations as a result. In order to recover the silver for reuse, hydrochloric acid would be added to precipitate it as the chloride ( $\text{AgCl}$ ). The silver would be recovered by either gravity settling or in a

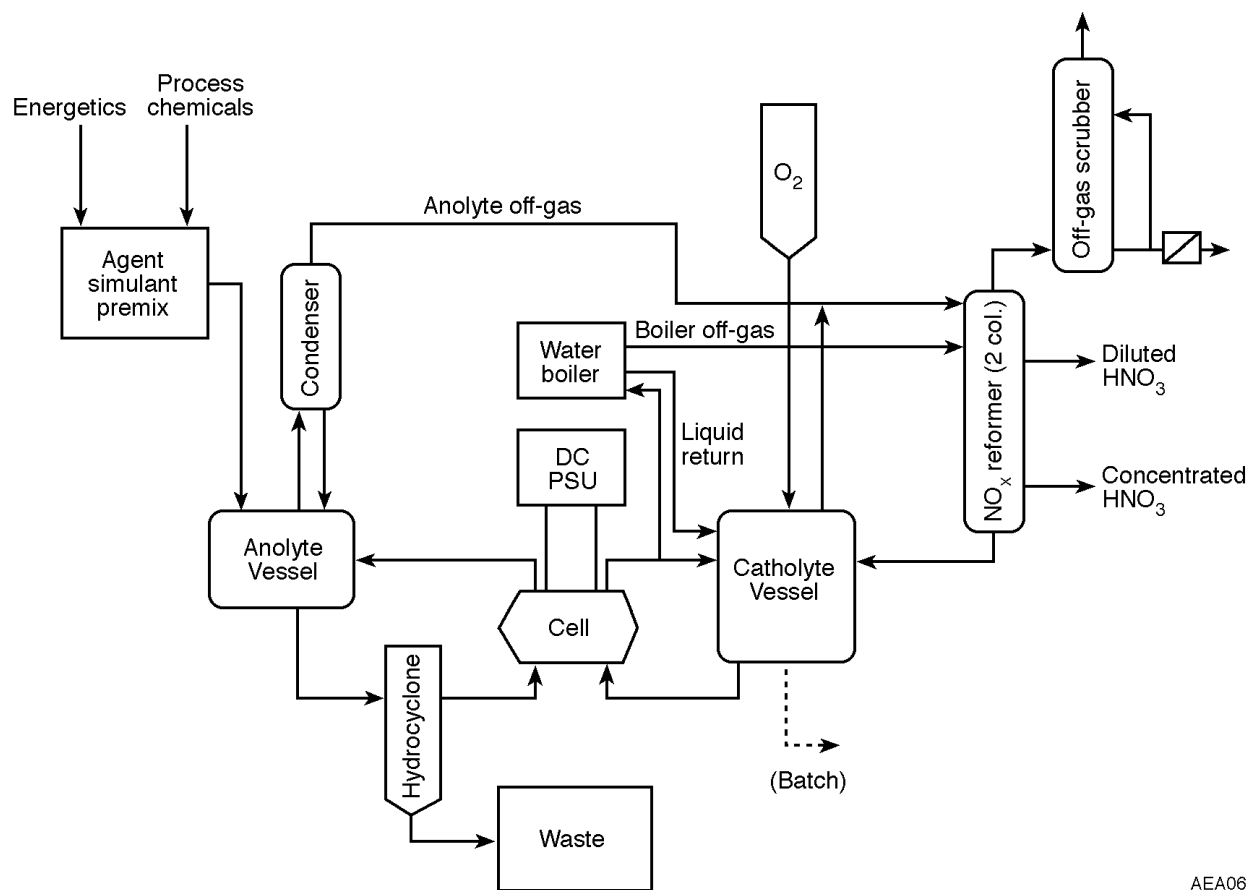


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**FIGURE 5.20 Process Flow Diagram for a SILVER II 2-kW Agent Plant Used in Demonstration Testing (Source: Adapted from AEA/CH2MHILL 2000)**

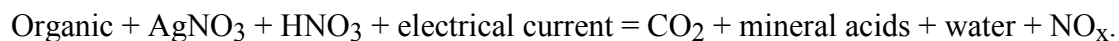
hydrocyclone. As AgCl may contain small traces of agent, AgCl would be treated to a 5X condition prior to being sent for silver recovery. The condensate from this process would be returned to the catholyte of the SILVER II system. The precipitator overflow would then be fractionally distilled to recover water and HNO<sub>3</sub> for recycle to the SILVER II catholyte (to create the AIRS and EIRS purge flow returns). The evaporator bottoms would contain some residual HNO<sub>3</sub> as well as enriched phosphoric and sulfuric acids. These, together with the HF stream, would subsequently be neutralized with lime to precipitate insoluble fluoride, phosphate, and sulfate salts of calcium. This stream could then be treated to a 5X condition. The condensate would be returned to the catholyte of the SILVER II system.

The SILVER II process is based on the highly oxidizing nature of Ag<sup>2+</sup> ions in a HNO<sub>3</sub> solution. Ag<sup>2+</sup> ions are among the strongest oxidizing agents known; HNO<sub>3</sub> also makes a significant contribution to the oxidizing process (NRC 1999). The Ag<sup>2+</sup> ions are produced at the anodes of an electrochemical cell (NRC 1999). The overall chemical reaction can be summarized as follows:



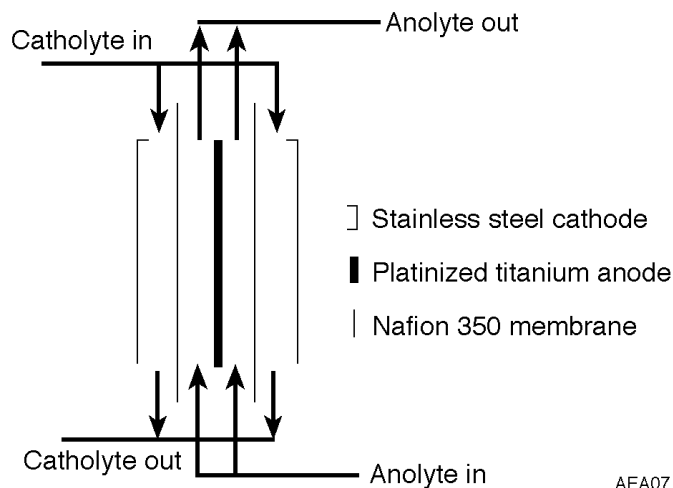
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**FIGURE 5.21 Process Flow Diagram for a SILVER II 12-kW Energetics Plant Used in Demonstration Testing (Source: Adapted from AEA/CH2MHILL 2000)**



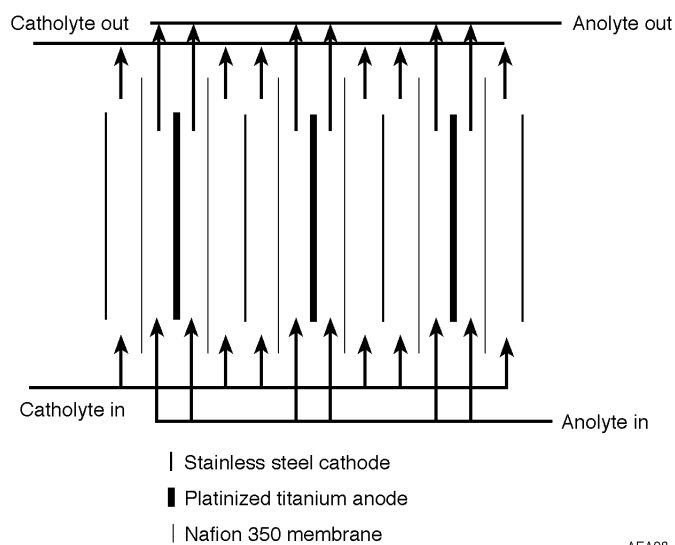
Generation of  $\text{Ag}^{2+}$  ions depends entirely on the electrical current, and it stops immediately when the power is switched off. This process ensures that the reaction is easily controllable. Electrical power to the cell can be shut off safely at any time (e.g., from safety interlocks at other stages of the overall process). A standard industrial electrochemical cell is at the heart of the SILVER II process. Figure 5.22 is a schematic of the 2-kW electrochemical cell used in demonstration testing; Figure 5.23 is a schematic of the 12-kW system used in demonstration testing. Here again, it is probable that the same anode/cathode arrangement may be used for agent and energetics in the pilot-scale design.

The anode and cathode compartments of this cell are separated by a permeable membrane that prevents bulk mixing of the anolyte and catholyte solutions. These solutions are circulated



AEA07

**FIGURE 5.22 2-kW Anode/Cathode Arrangement Used in Demonstration Testing (Source: Adapted from AEA/CH2MHILL 2000)**



AEA08

**FIGURE 5.23 12-kW Anode/Cathode Arrangement Used in Demonstration Testing (Source: Adapted from AEA/CH2MHILL 2000)**

around separate closed loops between the cell and its reaction vessels. The organic material for destruction is continuously metered into the anolyte tank to match the rate of destruction.

$\text{Ag}^{2+}$  ions generated at the anode of the electrochemical cell react with the water and  $\text{HNO}_3$  of the anolyte solution to form a range of other oxidizing radicals ( $\cdot\text{OH}$ ,  $\cdot\text{NO}_3$ ). In turn, the  $\text{Ag}^{2+}$  ions and other oxidizing species react with the organic material delivered into the anolyte

vessel and are reduced to  $\text{Ag}^{1+}$  ions, nitrate ions, and water. The organic material is oxidized to  $\text{CO}_2$ ,  $\text{NO}_x$  (from the direct reaction with the acid), and traces of CO and protons ( $\text{H}^+$ , not hydrogen gas), and inorganic salts. Off-gas from the reaction passes from the anolyte vessel via a condenser (to return  $\text{HNO}_3$  and organic vapors) to an  $\text{NO}_x$  reformer.

To balance the electrochemical reaction in the anolyte, a supporting cathode reaction occurs that involves reducing  $\text{HNO}_3$  to nitrous acid and water, while other reduction reactions generate  $\text{NO}/\text{NO}_2$ . The gases pass from the catholyte tank to the  $\text{NO}_x$  reformer.

The process is operated at a temperature of approximately 190°F (90°C) and at atmospheric pressure. As a result of the electrochemical reaction,  $\text{HNO}_3$  is consumed in the catholyte circuit, which results in the formation of gaseous  $\text{NO}_x$ . Water is transferred across the membrane in the electrochemical cell from the anolyte to the catholyte. In addition,  $\text{Ag}^{1+}$  ions are also transferred across the cell membrane, together with a small amount of organic material, depending on the organic feed to SILVER II. To maintain steady-state operating conditions, the operation incorporates internal recycle streams to return the silver and organic material to the anolyte circuit. This ensures that a buildup of organic material or silver in the catholyte does not occur and that steady-state conditions can be maintained.

The off-gas streams from the anolyte and catholyte circuits would be combined and sent to the  $\text{NO}_x$  reformer system. The reformer would recover the  $\text{NO}_x$  by removing it from the gas stream and would recycle it into concentrated  $\text{HNO}_3$  for return to the anolyte and catholyte circuits as required; or alternatively, the excess can be marketed as a product. A dilute stream of  $\text{HNO}_3$  less than 1% weight would also be produced. The technology provider plans to send this material to either an on- or off-site wastewater treatment facility. The dilute  $\text{HNO}_3$  stream may also be recycled within the plant.

The post-treatment portion of SILVER II also consists of a caustic scrubber and a number of CSTRs for adjusting the pH.  $\text{NO}_x$  in the off-gas is collected by a  $\text{NO}_x$  absorber column and reformed to  $\text{HNO}_3$  which is concentrated in a packed bed distillation column. The remaining off-gas from the  $\text{NO}_x$  reformer goes to a caustic scrubber for acid neutralization. HF distilled by the AIRS is neutralized with lime in a CSTR. Similarly, the pH of dilute  $\text{HNO}_3$  waste is neutralized with caustic.

After leaving the  $\text{NO}$  reformer, all off-gas passes through a caustic scrubber to remove very low levels of residual  $\text{NO}_x$ , thus leaving a stream of  $\text{CO}_2$ , oxygen, and water vapor. The off-gas is then tested to ensure that no agent is released from SILVER II. This off-gas stream is then processed through the catalytic oxidation process as a polishing step to ensure that trace organics are destroyed. Silver chloride is precipitated when mustard is exposed to the  $\text{HNO}_3$  and  $\text{AgNO}_3$  in the anolyte vessel. In the anolyte circuit, a hydrocyclone is used to continuously remove the  $\text{AgCl}$  from the recirculating liquid before it reaches the electrochemical cell.



The AgCl is accumulated in a settling vessel and discharged into an oven for 5X treatment on a batch basis. The vapor from the oven is passed to a condenser, and the condensate is returned to the anolyte vessel for destruction of any organic material that may be present. The AgCl is then removed as a solid cake for silver reclamation. Silver reclamation may be conducted on- or off-site.

#### **5.2.4.5.5 Metals Parts Treatment**

Metal parts would be treated to achieve a 5X condition in the MPT, as explained previously. The objective of this unit operation would be to elevate the temperature of the parts to over 1,000°F (538°C) for a period of at least 15 minutes. The PMACWA previously demonstrated this concept at CAMDS and during ACWA Demo I. Metal parts treatment would be accomplished in a chamber designed to receive the various metal parts containers, such as the projectile casing conveyance trays. The metal parts containers would be automatically conveyed into the chamber. The chamber would use electrical heating elements to achieve the design temperature. Steam would be passed through the chamber to enhance the exposure of metal to elevated temperatures and to establish the conditions of 5X treatment. The discharged steam would be condensed and the off-gas would be sent to the catalytic oxidation process for destruction of trace organic compounds, and then to carbon filtration, before discharge to the atmosphere. Two decontamination chambers would be used so that one chamber would be in load and 5X treatment phase, while the second chamber would be in the cool-down and unload phase. Decontaminated metal parts would be transported off-site for either recycling or disposal, in accordance with regulatory requirements.

The specific design of the detonation chamber will be optimized during EDS-II, but the conceptual design indicates that two detonation chambers would be sufficient to provide adequate capacity and to provide redundancy to deactivate fuzes, boosters, and supplemental charges. The chamber would be loaded with a preapproved number of fuzes and detonation charges. The controlled detonation would deactivate the fuzes. The resulting metal fragments would be conveyed to the metal parts treatment process. Off-gas from the chamber would be processed through the catalytic oxidation process, and subsequently through carbon filters prior to discharge.

#### **5.2.4.5.6 Dunnage Treatment**

Dunnage treatment would use the same principle as that for metal parts to achieve 5X decontamination. Contaminated dunnage would be stored in a silo contained within the MDB and would be fed to a two-stage shredder for size reduction to nominal 2 to 3 in. (5 to 8 cm) particle sizes. This would be accomplished with commercially available shredding equipment. The shredded dunnage would be mechanically conveyed to the BRT. As indicated previously, this is essentially the same as the MPT, except that it is a rotary oven that operates as a continuous process. The chamber would be designed to expose the shredded dunnage to the

design temperature for a resident time of 30 minutes to provide a reasonable safety factor. Treated dunnage would be discharged into a storage hopper for subsequent placement in a landfill, in accordance with regulatory requirements.

The BRT thermally treats fluid-cutting grit and size-reduced, solid (mostly nonmetallic) secondary wastes (dunnage and rocket shipping and firing containers). The BRT is similar to the MPT; however, it is operated in continuous mode. Off-gas from the MPT and the BRT (mostly steam) would be condensed and sent to SILVER II for treatment. All process off-gas would be mixed with air, treated with a catalytic oxidation system, and passed through carbon filters before release to the atmosphere.

#### **5.2.4.5.7 Effluent Management and Pollution Controls**

The SILVER II process produces various types of waste. The process off-gases are passed through a catalytic oxidation unit, carbon filtered, and tested (with carbon filter rework as necessary) before exhausting to the atmosphere. Liquids are separated by evaporator and condensers and are reused (on- or off-site) or sent off-site for treatment, as necessary, and disposal. Evaporator bottoms from the impurities removal systems are treated as necessary and disposed of off-site. The pH-adjusted acid streams would undergo wastewater treatment either on- or off-site. Solids from HF neutralization would be de-watered in a filter press, treated as necessary, and placed in a landfill. Metals that had been decontaminated to a 5X condition would be recycled, and 3X/5X solids would be treated as necessary and then placed in a landfill. All waste management would be conducted in compliance with regulatory requirements. As indicated previously, hazardous wastes may be delisted from being hazardous wastes if regulatory delisting criteria are met.

Silver is used to catalyze the oxidation of organics. Normally, this silver remains in solution, except in those instances in which compounds containing chlorine are present (e.g., mustard). Silver combines with chlorine contained in mustard agent to create AgCl, which must be removed from the system. This would be accomplished by using hydrocyclones that separate the precipitated AgCl from the anolyte solution in the plant. The material would then be decontaminated in a 5X oven. The resulting material would be collected and transported off-site. Silver would be reclaimed at a commercial facility. If necessary, this reclamation process can occur on-site.

Concentrated HNO<sub>3</sub> is a product of the SILVER II process when treating energetic materials that contain nitrogen. These materials can be transported off-site for reuse in the manufacture of energetics (assuming a 5X condition is met). Dilute HNO<sub>3</sub> is also produced. This material could be recycled within the system. Any dilute HNO<sub>3</sub> that has not been recycled would be neutralized with scrubber waste and discharged to an on- or off-site wastewater treatment facility. Any materials sent off-site would need to meet U.S. Army safety standards.

#### 5.2.4.6 Common Elements – Other Systems

The electrochemical oxidation process has several elements that are identical or nearly identical to other systems. This commonality is particularly evident in pretreatment processes. Commonalities with other applicable technology systems include the following:

- The munitions access system used for electrochemical oxidation using SILVER II employs much of the baseline reverse assembly system, as do most of the other ACWA systems.
- Similar to the neutralization/biotreatment process, the munitions access system for the M55 rockets employs fluid jet cutting and fluid-mining to access energetics.
- Process off-gas is passed through catalytic oxidation units prior to carbon filtration and release to the atmosphere. This is also similar to the neutralization/biotreatment process and the neutralization/GPCR/TW-SCWO process.
- Dunnage would be size-reduced and treated in a manner similar to the neutralization/biotreatment technology.
- Decontamination of metal parts would occur thermally to a 5X condition using steam. The process would subject the parts to temperatures in excess of 1,000°F (538°C) for a period of more than 15 minutes. This process is similar to that used in the neutralization/biotreatment technology.

Facility structure; ventilation; decontamination fluid supply; personnel support; pollution abatement; water, air, and steam supply systems; control rooms; monitoring systems; and laboratory support would be identical or nearly identical to the baseline system.

#### 5.2.5 COMBINATION TREATMENT TECHNOLOGIES

Given the commonalities of the various technology systems, the elements of the various unit operations could be combined into different but viable ACW treatment alternatives. A number of different combination technologies may be considered. The following are examples of several combination technologies that could be employed:

- The cryofracture technology of neutralization/SCWO can be used with any system;<sup>58</sup>
- The fluid-abrasive cutting and fluid-mining technologies of neutralization/biotreatment can be used with any system;
- The specific units proposed for agent and energetic hydrolysis in the neutralization/SCWO, neutralization/biotreatment, or neutralization/GPCR/TW-SCWO systems are interchangeable;
- The metal parts treatment technologies proposed for neutralization/ SCWO, neutralization/biotreatment, or neutralization/GPCR/TW-SCWO are interchangeable;
- The CatOx unit, used in neutralization/biotreatment, neutralization/GPCR/TW-SCWO, and electrochemical oxidation, can be employed with any technology system; and
- Carbon filtration, as used in the baseline process and in most of the ACWA technologies, may be used with any technology system.

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<sup>58</sup> This process, however, may not perform well with aluminum-bodied munitions such as M55 rockets.

### **5.3 SUPPLEMENTAL INFORMATION FOR ASSEMBLED SYSTEMS AT BLUE GRASS ARMY DEPOT**

This section provides supplemental information for pilot testing ACWA technology systems at BGAD. Included are facility descriptions, system inputs and resource requirements, routine emissions and wastes, and activities and schedules. This section addresses construction and operation of the facility. As the pilot-scale facility designs mature, deviations are expected. However, it is anticipated that the final design would result in estimates similar to those provided in the tables in this section.

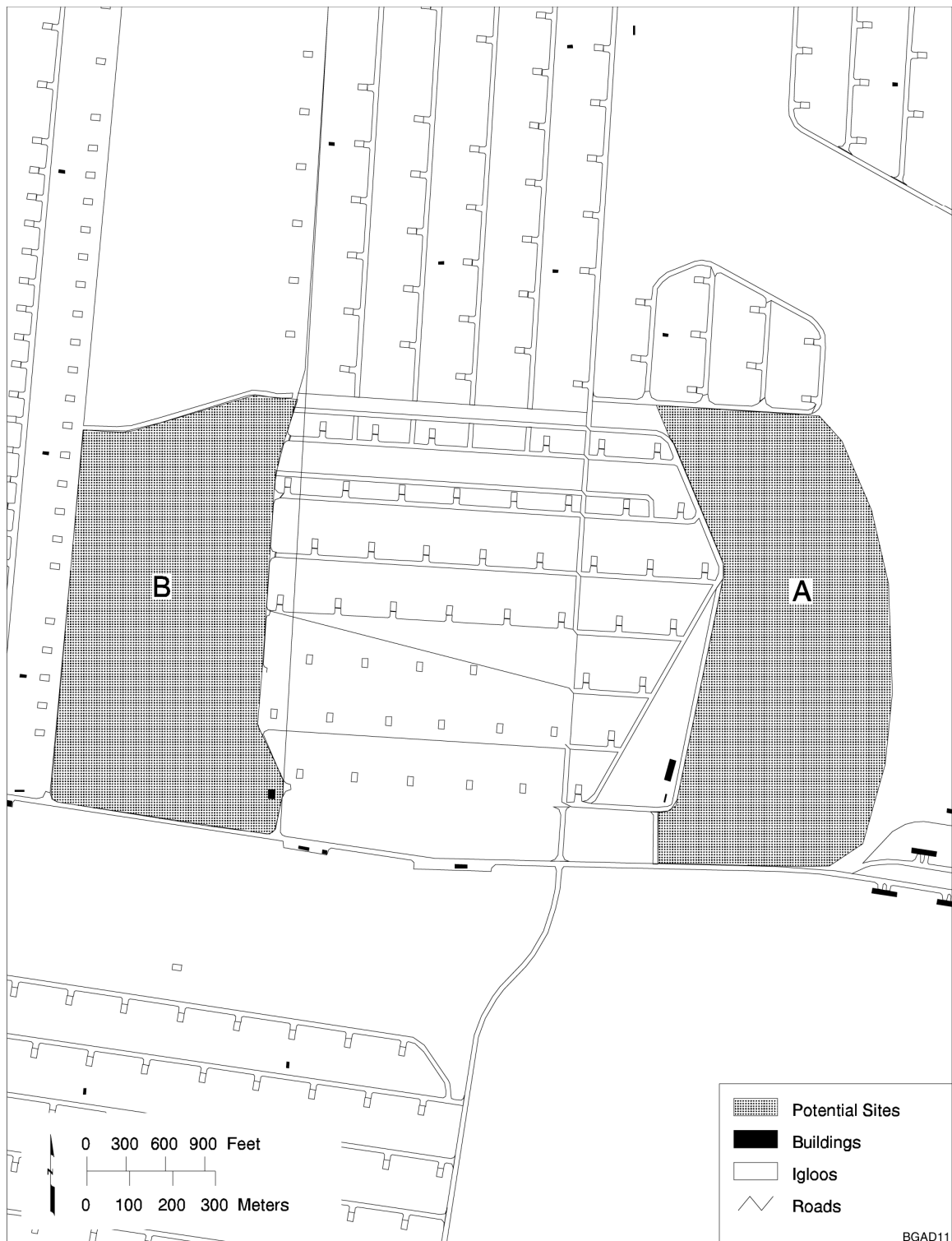
#### **5.3.1 GENERAL FACILITY LOCATION AND FOOTPRINT**

For the purposes of NEPA assessment, it has been assumed that all ACWA program facilities would be constructed within the chemical demilitarization reuse area located in the central/north-central portion of BGAD. Figure 5.24 shows the two possible sites (Sites A and B) for the demilitarization facility within this area. These two sites are adjacent to the existing ACW storage area; one is to the east and one is to the west. This analysis focuses on the potential location of the ACWA facility within Areas A and B. The exact location of the actual demilitarization facility within these two areas has yet to be determined. It is possible that multiple ACWA technologies would be tested at BGAD.

In general, the physical size of the destruction facility for ACW at BGAD is expected to be comparable to that required for baseline incineration. The facility size may differ slightly as a function of technology system alternative. For each technology system, the facility is expected to cover an area of approximately 20 to 30 acres (8 to 12 ha), with additional land area of up to 20 acres (8 ha) needed for construction support facilities. Additional acreage may be required for access roads and utilities; the area required would be determined on a site-specific basis. The facility size may differ slightly as a function of the technology system alternative. Table 5.5 provides approximate distance information for each of the two sites, and Table 5.6 provides land area requirements during operations.

The land area required during construction may be greater than that required during operations because of the need for the following:

- A construction lay-down area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit;
- Temporary construction offices for housing on-site engineering personnel and construction supervision and management personnel;
- Temporary parking for construction workers and support personnel;



**FIGURE 5.24 Map Showing Two Potential Locations for the Demilitarization Facility at BGAD**

**TABLE 5.5 Approximate Distances from Potential Demilitarization Facility Locations A and B to BGAD Installation Boundaries (mi)<sup>a</sup>**

Location	Distance to North BGAD Boundary	Distance to South BGAD Boundary	Distance to East BGAD Boundary	Distance to West BGAD Boundary
A	1.1	3.7	1.5	3.3
B	1.0	3.6	2.5	2.3

<sup>a</sup> Distance (in miles) determined from the approximate midpoint of Areas A and B, respectively, as shown in Figure 5.24.

**TABLE 5.6 Land Area Requirements during Technology Systems Operations**

Technology	Land Area for Operations (acres)
Baseline incineration	20
Neutralization/SCWO <sup>a</sup>	20–30
Neutralization/biotreatment <sup>b</sup>	20
Neutralization/GPCR/TW-SCWO <sup>c</sup>	25
Electrochemical oxidation	20

<sup>a</sup> Based on Figure 4.3-8 in General Atomics (1999).

<sup>b</sup> Based on Figure 4.3.1-1 in Parsons/Allied Signal (1999) and stated similarly to incineration facility layout.

<sup>c</sup> Based on PMACWA (2001c).

- Temporary holding basins for control of surface water runoff during construction; and
- Areas for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

The additional land area for construction-related activities would, in general, be on the order of 10 to 20 acres (8 to 12 ha). This analysis conservatively assumes that a total of 50 acres (20 ha) would be required for construction purposes. Examination of the available land area at Sites A and B indicates that the above construction-related areas would be readily available at each of these locations.

Existing security fencing along the perimeter of the current chemical storage area would be extended to include the proposed ACW destruction site, thereby creating a contiguous fenced area around the storage area and the destruction site. The storage area and destruction site would be separated by security fencing to control access. A buffer area around the proposed destruction site would be established as defined by the Public Access Exclusion Distance required by the U.S. Army. This distance is defined as the greater of the fragmentation hazard distance or the 1% lethality distance (U.S. Army 1997). Site personnel not directly associated with the demilitarization operation would be excluded from the buffer area defined by this distance, or provision would be made for their protection or evacuation.

Both Areas A and B consist of flat and sloping terrain with one minor exception (see Figure 5.24). Neither Area A or B has existing structures; thus, no significant demolition or removal of structures is anticipated. However, the extent of these activities is dependent on the exact location of the facility within the areas bounded by Areas A and B.

Construction of the demilitarization facility would involve small amounts of excavation and fill work. Construction debris would be transported off-site to a commercial disposal facility. A drainage system would be established for the facility to divert surface runoff from the plant site and to prevent erosion and accumulation of surface water on the facility. Moderate clearing and earthwork would be required in Areas A and B.

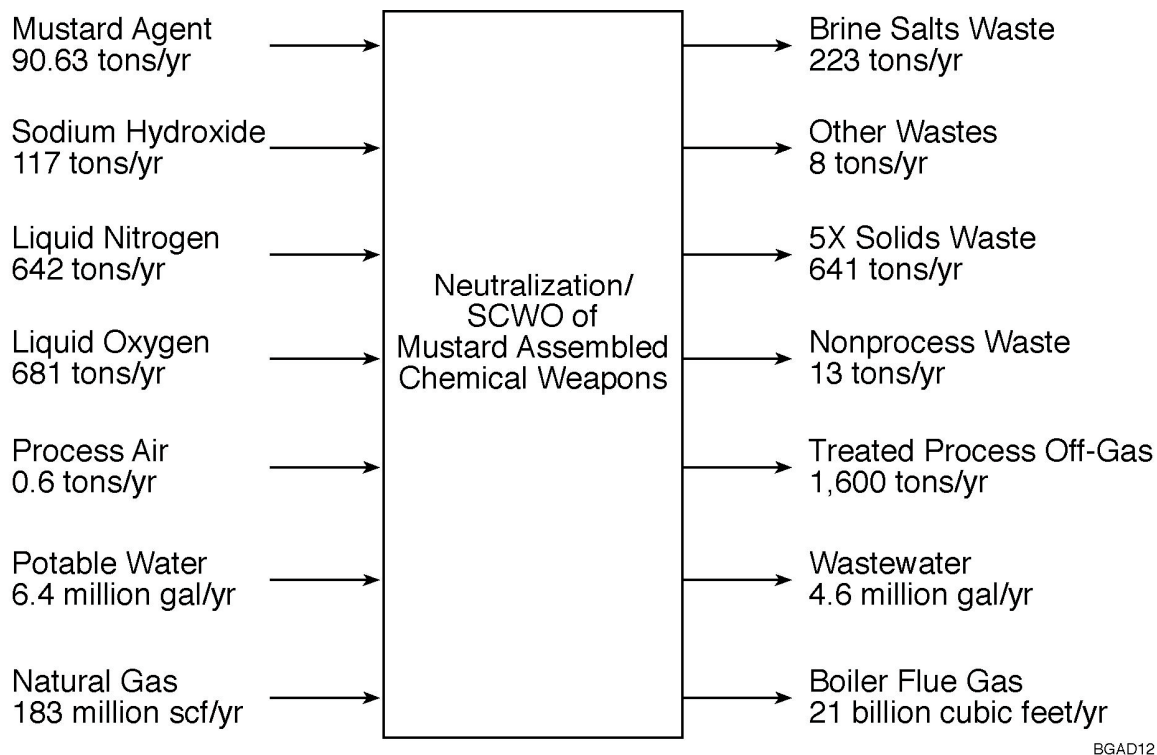
### 5.3.2 NEUTRALIZATION/SCWO

This description of the neutralization/SCWO facility is based on preliminary design information provided in General Atomics (1999). In that report, many of the estimates provided for facility design refer comparatively to the U.S. Army baseline incineration process, which indicates, in general, that estimates are comparable to those associated with the baseline incineration process (General Atomics 1999). Thus, another of the primary sources of information for this section of the TRD is the EIS for disposal of chemical agents and munitions stored at Pine Bluff Arsenal, Arkansas (PMCD 1997). That is the most recent EIS that the U.S. Army has prepared for baseline incineration of chemical munitions.

In addition to the above, mass balance estimates, air emission estimates, and solid waste estimates for application of the neutralization/SCWO technology at BGAD have been developed (Mitretek 2001b). Air emissions and solid waste estimates for neutralization/SCWO, as discussed below, are based on Mitretek inputs (Mitretek 2001b), along with appropriate assumptions on filtration systems and plant operations and schedule. Figures 5.25 and 5.26 provide an input/output material balance for the major streams for neutralization/SCWO of ACW containing mustard agent and nerve agent, respectively.

Many of the figures and tables referred to in the facility description for this technology system contain estimates (e.g., emissions, resources consumed) associated with processing ACW



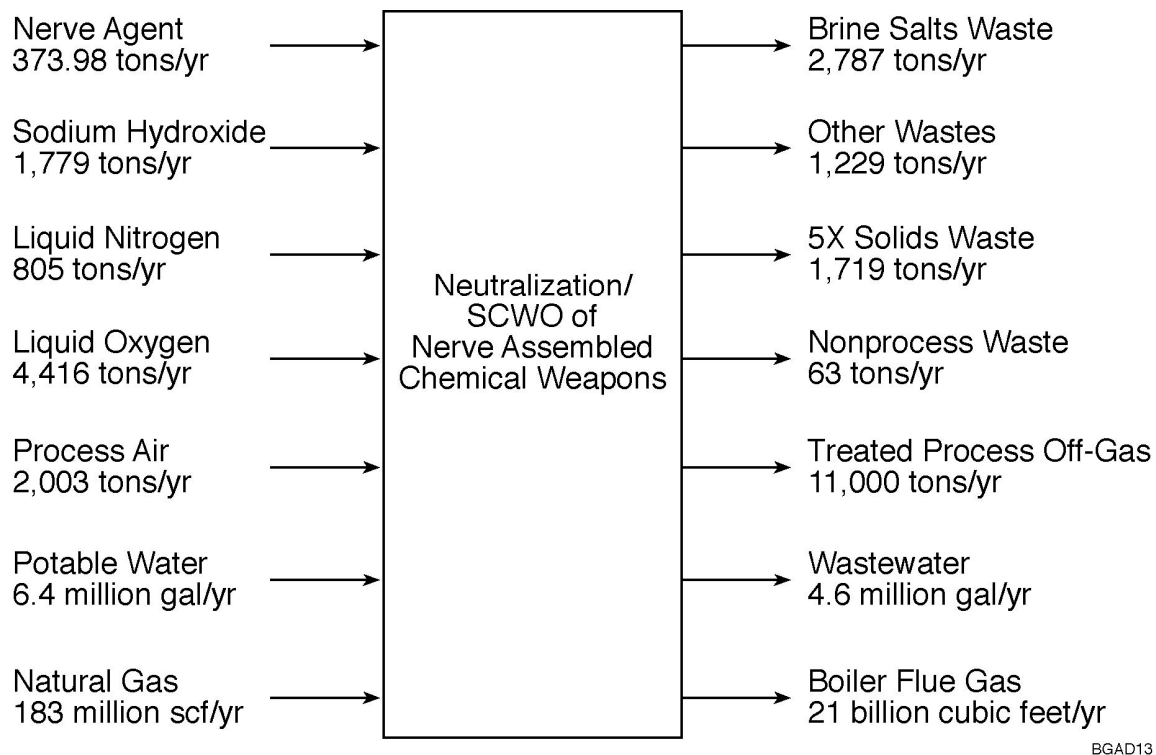


**FIGURE 5.25 Input/Output Material Balance for Neutralization/SCWO of ACW Containing Mustard Agent at BGAD**

with a specified agent; these estimates are given on an annual basis (e.g., tons/yr). In some cases, the estimates have been converted from other units (e.g., lb/d) by accounting for the number of days of operation required for processing a specific type of ACW. This time period is referred to as a campaign; a campaign is agent-specific. The values in many of the following figures and tables are based on the number of days in the campaign required to process ACW containing a specific agent. It was assumed that there are 276 operating days in a year. If the campaign is less than or equal to 276 days, annual quantities equal total quantities. If the campaign is greater than 276 days, quantities in the figures and tables are for 276 days of processing. In the latter case, the estimates provided are less than total quantities. Daily (or other) quantities may be obtained by adjusting for the number of days in the campaign.

### 5.3.2.1 General Facility Description

The proposed neutralization/SCWO facility is designed to fit approximately into the same space and general configuration as the baseline incineration process. Munitions access and disassembly, neutralization, and SCWO operations have been substituted for baseline incineration operations. The physical plant would consist of a two-story building constructed of noncombustible materials, with a concrete structural frame and a low-slope concrete roof.



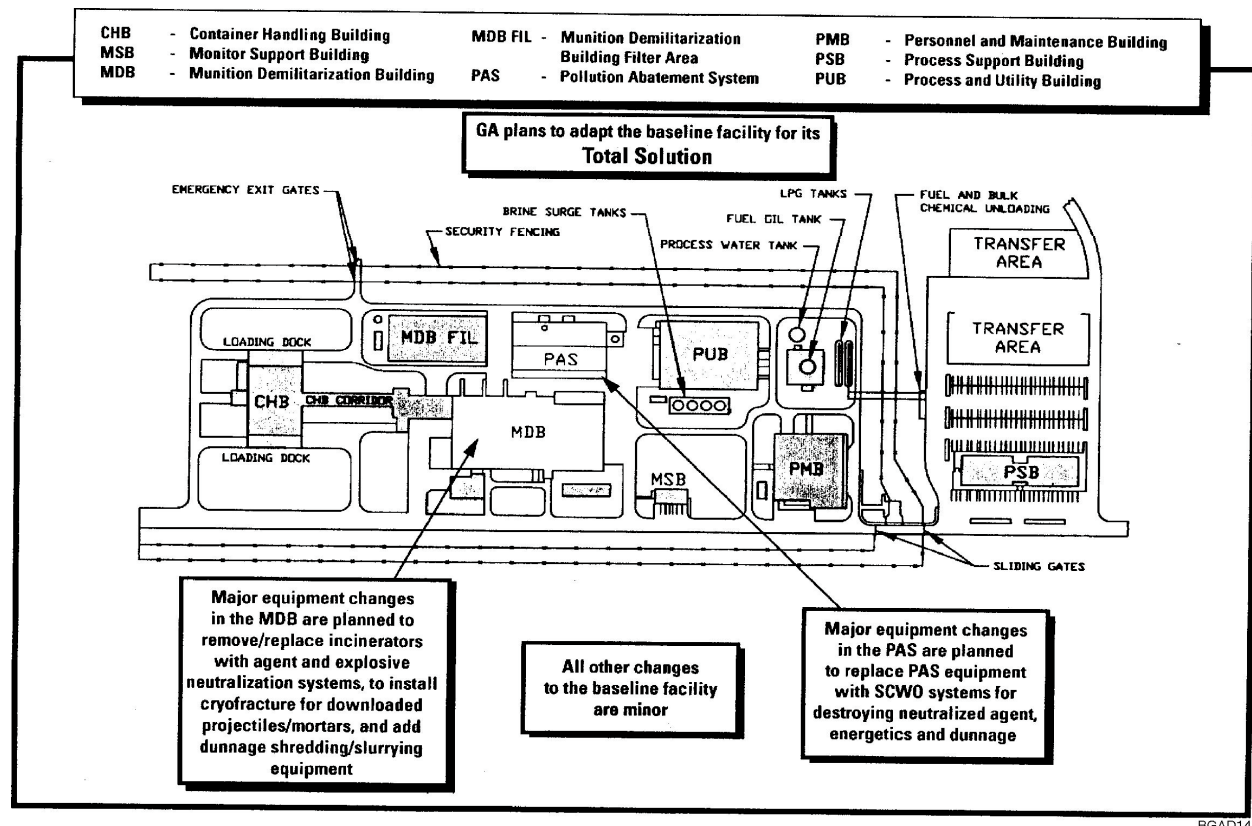
**FIGURE 5.26 Input/Output Material Balance for Neutralization/SCWO of ACW Containing Nerve Agent at BGAD**

The site layout for the neutralization/SCWO facility is shown in Figures 5.27 through 5.29. Figure 5.27 shows the general facility layout, Figure 5.28 shows the layout of the first floor, and Figure 5.29 shows the layout of the second floor.

### 5.3.2.2 Construction Phase

The schedule for destruction of the stockpile at BGAD, although tentative, calls for construction of the selected alternative to begin following issuance of the EIS Record of Decision (ROD) and receipt of the RCRA and any other environmental permit, as necessary. It is anticipated that the construction schedule for the neutralization/SCWO facility would not differ significantly from that required for baseline incineration. Construction would take approximately 34 months (General Atomics 1999), including a two-month design and procurement verification period. However, the PMACWA is investigating means of shortening the construction phase.

Construction of the destruction facility on the BGAD installation would result in vehicle exhaust emissions, fugitive dust, noise, destruction of wildlife habitat and native vegetation, increased employment, increased demand for public services, and occupational health hazards.



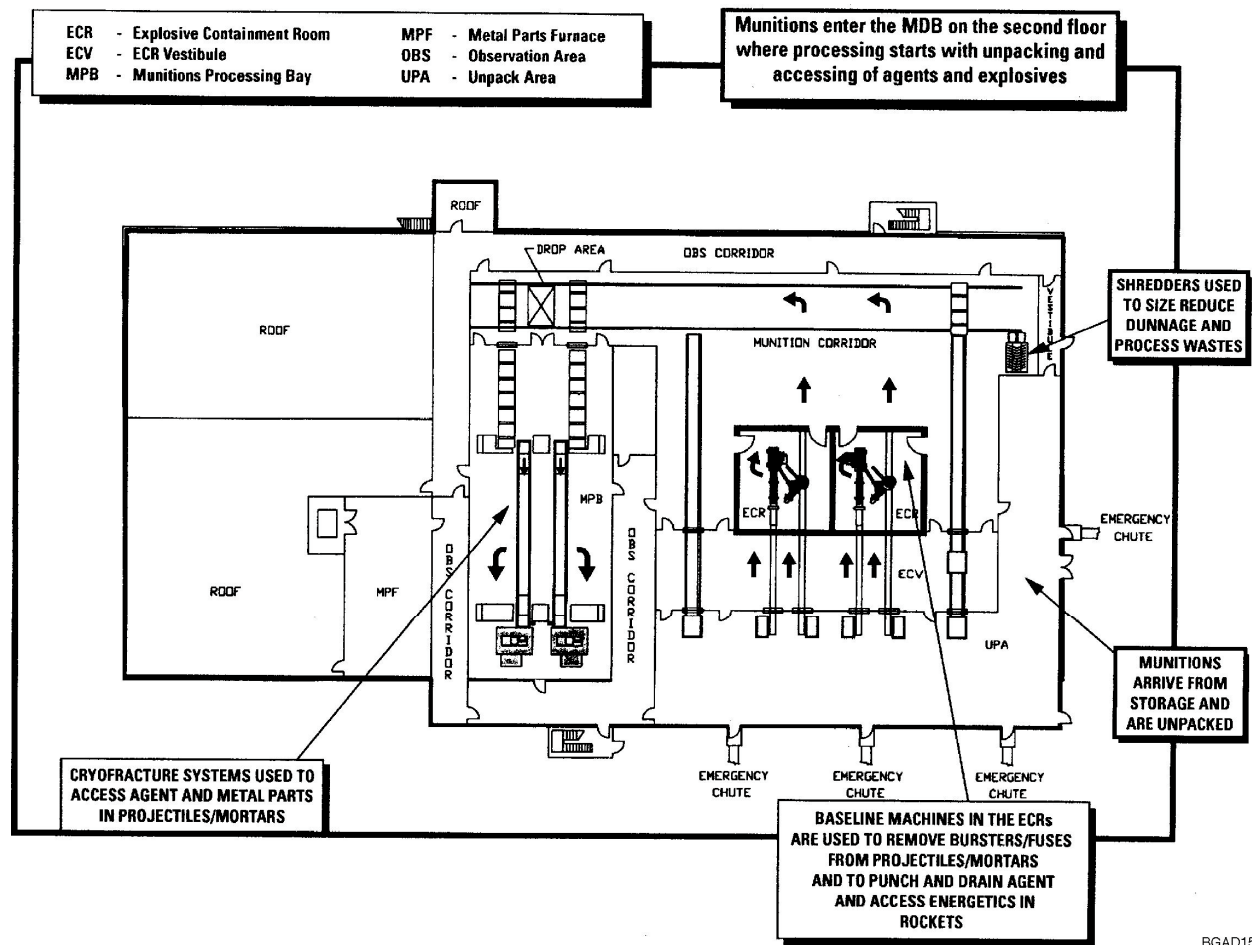
**FIGURE 5.27 Neutralization/SCWO Facility Arrangement at BGAD (Source: General Atomics 1999)**

### 5.3.2.2.1 Construction Inputs and Resource Requirements

The PMACWA has estimated that the capital cost for the neutralization/SCWO process at BGAD would be approximately 5% less than that required for construction of the baseline incineration system (PMACWA 1999b). Resources needed for facility construction include water, electricity, concrete, steel, liquid fuels, lumber, and industrial gases (e.g., propane). Table 5.7 provides estimates of construction materials consumed during construction.

The process equipment would be purchased from equipment vendors. Specialty materials, such as Inconel or Monel, do not appear to be required. However, the SCWO reactors may require platinum or an alternative specialty material as an anticorrosive barrier in the final design (PMACWA 1999a).

Table 5.8 provides an order-of-magnitude estimate of the number of shipments of construction materials to the site. The estimate does not include process equipment and related items; the number of shipments associated with these resources is expected to be small in comparison with the estimate of 5,000 total shipments.

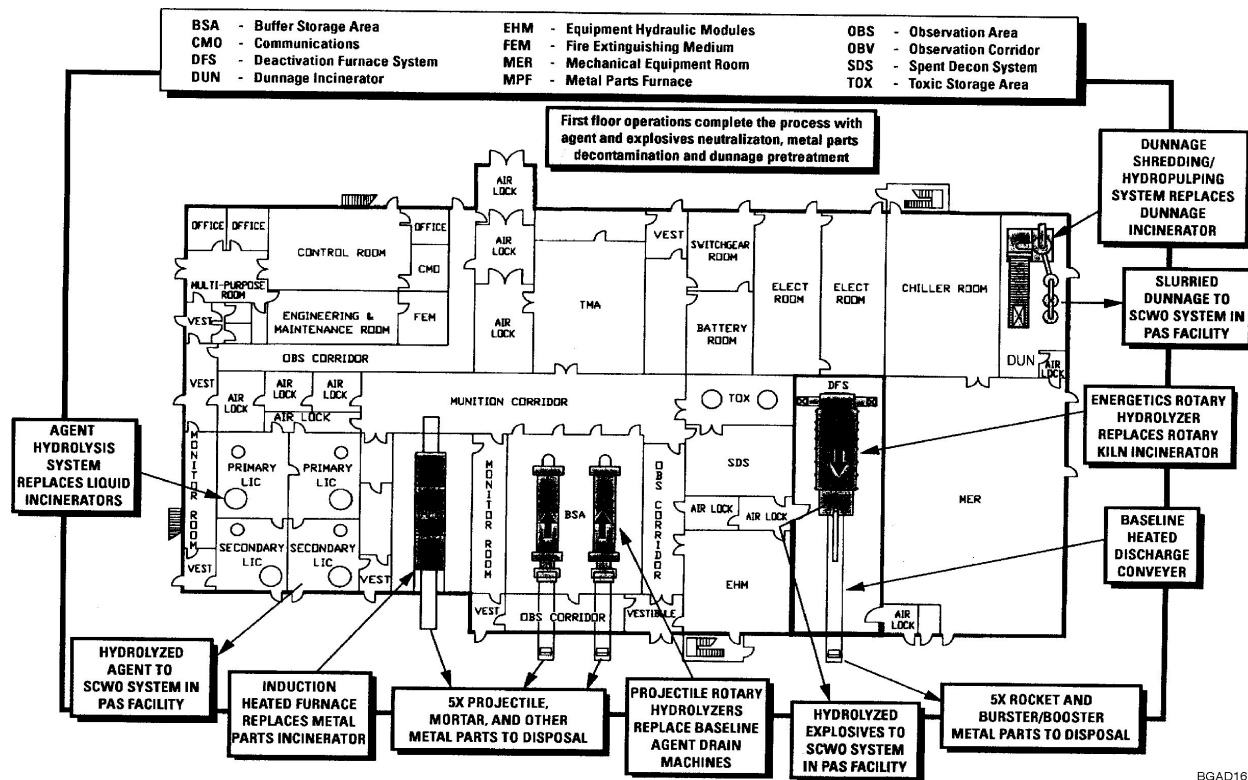


**FIGURE 5.28** Layout of First Floor of the Munitions Demilitarization Building for the Neutralization/SCWO Facility at BGAD (Source: General Atomics 1999)

Table 5.9 gives an order-of-magnitude estimate of the emissions from construction delivery vehicles to the site, assuming a one-way trip distance of 20 mi (32 km) (roughly equal to the distance to the outskirts of Lexington) and delivery by heavy-duty diesel trucks. The actual trip distances would depend on several factors, including the availability of construction materials from local distributors and the distance of the site from the distributors.

### 5.3.2.2.2 Construction Workforce

The construction workforce is expected to steadily increase to a peak of about 930 full-time equivalent (FTE) employees near the midpoint of the construction period, and then to decrease steadily until construction is completed. The average number of construction workers is estimated to be approximately 490 FTEs. When a 34-month construction period is assumed, approximately 1,300-FTE-years of effort would be expended during construction. Table 5.10 provides an estimate of the employment buildup by year during construction.



BGAD16

**FIGURE 5.29** Layout of Second Floor of the Munitions Demilitarization Building for the Neutralization/SCWO Facility at BGAD (Source: General Atomics 1999)

### 5.3.2.2.3 Construction Emissions and Waste Estimates

During the construction phase, fugitive emissions would consist mainly of dust and vehicle exhaust. Temporary, regional increases in atmospheric concentrations of CO, NO<sub>x</sub>, hydrocarbons, particulate matter, and sulfur oxides (SO<sub>x</sub>) would result from the exhaust emissions of commuter vehicles, heavy construction vehicles, diesel generators, and other machinery and tools. Annual emissions of these pollutants would be small in comparison to de minimis levels typically used by regulators to determine whether an air quality permit or impact analysis is necessary. Emissions from construction vehicles are exempt from permit requirements. Nevertheless, vehicles and machinery would be equipped with standard pollution control devices to minimize air quality impacts.

Estimated criteria pollutant emissions from construction activities (not including emissions from delivery vehicles) are shown in Table 5.11. The emissions listed are based on the anticipated construction land disturbance and vehicle traffic (for dust particulate pollutants) and fuel and gas consumption. The column marked "Total" indicates the total amount of emissions that is estimated to occur over the entire construction period.

**TABLE 5.7 Estimated Materials/Resources Consumed during Construction of a Neutralization/SCWO Facility at BGAD<sup>a</sup>**

Construction Material/Resource	Total Consumption	Peak Demand
Utilities		
Water <sup>b</sup>	8,000,000 gal	NA <sup>c</sup>
Electricity	54,000 MWh	2.7 MW
Solids		
Concrete	32,300 yd <sup>3</sup>	NA
Steel (structural and reinforcing)	7,100 tons	NA
Piping (all)	123,000 linear ft	NA
Liquids		
Fuel	2.4E+06 <sup>d</sup> gal	NA
Gases		
Industrial gases (propane)	6,500 gal	NA

<sup>a</sup> All values can be considered to be order-of-magnitude approximations of the actual values; more accurate values would require a detailed consideration of construction activities.

<sup>b</sup> The water requirement was estimated on the basis of DOE (1997), in which each full-time equivalent (FTE) required 20 gal/d, and solidification required 26 lb per 100 lb of cement.

<sup>c</sup> NA = not applicable.

<sup>d</sup> This system of notation is equivalent to  $N \times 10^{+x}$ ; for example,  $2.4E + 06$  equals  $2.4 \times 10^6$ .

Emissions from construction worker commuter vehicles were estimated on the basis of the assumption that an average of 486 automobiles (1 car per construction worker) would be added to the area. Table 5.12 gives the annual emissions estimates due to the increased traffic.

Additional emissions would result from the use of paints and thinners, aerosols, and other area source emissions. These emissions are expected to be minor contributors to air pollution and were not included in current estimates.

Construction would generate solid wastes primarily in the form of excavation spoils and building material debris. These latter wastes would include concrete forms, equipment and hardware containers and packaging, paint cans, waste metal sheeting, pipe and wire, and landscaping debris. Small amounts of liquid wastes, such as solvents, cleaning solutions, and paint wastes also would be generated. Wastes would be collected and disposed of in compliance with U.S. Army, federal, state, and local requirements. All construction debris would be removed from the site for disposal. Any batteries, used motor oils, and empty containers would be separated from the waste stream and recycled. Any wastes identified as hazardous would

**TABLE 5.8 Order-of-Magnitude Estimate of the Number of Truck Shipments of Construction Materials<sup>a</sup> for a Neutralization/SCWO Facility at BGAD**

Resource	Total Consumption	Truck Capacity	No. of Truck Shipments
Portland cement <sup>b</sup>	3,553 yd <sup>3</sup>	10 yd <sup>3</sup>	356
Gravel <sup>b</sup>	13,243 yd <sup>3</sup>	10 yd <sup>3</sup>	1,325
Sand <sup>b</sup>	8,398 yd <sup>3</sup>	10 yd <sup>3</sup>	840
Steel <sup>c</sup>	7,100 tons	21 tons	340
Asphalt paving <sup>d</sup>	1,200 tons	20 tons	60
Backfill <sup>e</sup>	12,800 yd <sup>3</sup>	10 yd <sup>3</sup>	1,280
Fuel <sup>f</sup>	2.4E+06 gal	9,000 gal	270
Total			4,471
Total (rounded up)			5,000

<sup>a</sup> The calculation did not include truck deliveries of process equipment and related items.

<sup>b</sup> Assumes that concrete is composed of 11% portland cement, 41% gravel, and 26% sand and is shipped to the site in a standard 10-yd<sup>3</sup> end-dump truck.

<sup>c</sup> Assumes that the net payload for steel transport to the site is 42,000 lb.

<sup>d</sup> Assumes that hot mix asphalt (HMA) is loaded into 20-ton-capacity triaxle trucks for transport to the paving site.

<sup>e</sup> Assumes that shipment is in standard 10-yd<sup>3</sup> end-dump trucks and that no fill material is available on-site.

<sup>f</sup> Assumes that shipment is in a U.S. Department of Transportation (DOT) 406/MC-306 atmospheric pressure tank truck with a 9,000-gal capacity.

be stored and disposed of in accordance with RCRA requirements. Sanitary wastes would be the only significant liquid effluents that would be generated during construction and would be managed on-site.

The estimated total quantities of solid and liquid wastes generated from activities associated with facility construction are shown in Table 5.13. The waste generation quantities are based on historical data on land area size and the construction labor force.

### 5.3.2.3 Operations Phase

Information on the facility operations phase is presented in this section. Preoperational testing is discussed first, followed by facility inputs and resource requirements, workforce requirements, and emissions and waste estimates.

**TABLE 5.9 Estimated Emissions from Delivery Vehicles during Construction of a Neutralization/SCWO Facility at BGAD**

Criteria Pollutant <sup>a</sup>	No. of Auto Round Trips <sup>b</sup>	Emission Factor (g/km) <sup>c</sup>	One-Way Trip Distance (mi) <sup>d</sup>	Construction Period (yr)	Emission Rate (tons/yr)
HC	5,000	2.12	20	2.8	0.3
CO	5,000	11.28	20	2.8	1.4
NO <sub>x</sub>	5,000	1.25	20	2.8	0.2
SO <sub>x</sub>	5,000	0.23	20	2.8	0.03
PM <sub>10</sub>	5,000	0.617	20	2.8	0.1

<sup>a</sup> Abbreviations: CO = carbon monoxide, HC = hydrocarbons, NO<sub>x</sub> = nitrogen oxides, PM<sub>10</sub> = particulate matter with a diameter less than or equal to 10 micrometers, SO<sub>x</sub> = sulfur oxides.

<sup>b</sup> Number of auto round trips to the construction site estimated on the basis of the total number of deliveries.

<sup>c</sup> Emission factors determined by using U.S. Environmental Protection Agency (EPA) modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>d</sup> One-way trip distance based on DOE (1997).

**TABLE 5.10 Estimated Number of Employees Needed by Year for Construction of a Neutralization/SCWO Facility at BGAD**

Employees	Year 1	Year 2	Year 3
Total craft workers	260	590	190
Construction management and support staff	70	150	50
Total	330	740	240

### 5.3.2.3.1 Preoperational Testing

A preoperational testing period assumed to last between 8 and 15 months would begin following facility construction (PMACWA 1999b). Often referred to as systemization, this period would be used to ensure that systems are operating as designed prior to pilot-scale operations. On the basis of similarity with baseline operations, it is projected that 315 FTEs would be needed at the peak of preoperational testing.

**TABLE 5.11 Estimated Criteria Pollutant Emissions during Construction of a Neutralization/SCWO Facility at BGAD**

Criteria Pollutant	Total (tons)	Annual (tons/yr)
CO	122	43
HC	51	18
NO <sub>x</sub>	181	64
SO <sub>x</sub>	12	4
Particulates <sup>a</sup>	522	184

<sup>a</sup> Estimated assuming that 50 acres would be disturbed during construction.



**TABLE 5.12 Estimated Criteria Pollutant Emissions from Construction Worker Commuter Vehicles during Construction of a Neutralization/SCWO Facility at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Emission Rate (tons/yr)
HC	117,000	1.16	20	9.6
CO	117,000	11.38	20	94.2
NO <sub>x</sub>	117,000	0.73	20	6.0
SO <sub>x</sub>	117,000	0.12	20	1.0

<sup>a</sup> Number of auto round trips to the construction site estimated on the basis of the average construction workforce and an assumption of 240 workdays per year.

<sup>b</sup> Emission factors were determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub>, and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

### 5.3.2.3.2 Operations Inputs and Resource Requirements

At full-scale operation, destruction of the mustard agent inventory at BGAD is projected to require 16 days for processing, and destruction of the nerve agent inventory is projected to require 319 days for processing (Mitretek 2001b). Destruction operations at BGAD are projected to require approximately 18.6 months at full-scale operation (see Table 5.14). This duration is based on a 12-hours-per-day, 6-days-per-day operation, 46 weeks per year, with two 6-week agent/munition changeover periods and two 2-week munition changeover periods (General Atomics 1999).<sup>59</sup>

Annual utility consumption for facility operation is presented in Table 5.15, including electricity, fuel, and potable water usage. The amount of process water that would be needed for steam generation and other processes has not been calculated, because the technology provider purports that this process is a net producer of water. Tables 5.16 and 5.17 show annual consumable chemical and process material usage during mustard agent and nerve agent processing, respectively. These estimates were based on an assumed average or normal throughput.

Tables 5.18 and 5.19 give transportation data for annual shipment of input material streams into BGAD for mustard agent and nerve agent processing, respectively. Hazardous materials shipped to the site include corrosives such as NaOH and phosphoric acid (H<sub>3</sub>PO<sub>4</sub>),

<sup>59</sup> The full-scale scenario has been selected as the bounding case for this analysis.

combustibles (kerosene), a nonflammable gas-oxidizer (oxygen), and a nonflammable liquid (nitrogen). Oxygen and nitrogen would be transported to the site as liquids.

#### 5.3.2.3.3 Operations Workforce

The neutralization/SCWO facility would be a government-owned, contractor-operated facility. The operating and maintenance labor for neutralization/SCWO is expected to be similar to that for incineration (General Atomics 1999; PMACWA 1999a). This analysis assumed that the estimated operations workforce needs would be approximately 571 contractor employees for plant operations and 150 government employees for munition handling, security, oversight, and other support activities (PMCD 1997).

#### 5.3.2.3.4 Operations Emissions and Waste Estimates

Wastes from the neutralization/SCWO process would include air emissions and solid wastes. The only liquid effluent expected from the destruction facility would be sanitary waste, which would be managed in an on-site treatment unit. All liquids generated by the process and all liquid laboratory wastes would be reused in the process or destroyed internally by neutralization/SCWO. Destruction facility operations, including waste management, would comply with U.S. Army, federal, state, and local requirements. Any wastes that are identified as hazardous would be stored and disposed of in compliance with RCRA requirements. A summary of the types of emissions and solid wastes is provided below.

**Atmospheric Emissions.** The major process gaseous residuals expected from the neutralization/SCWO operation include the following:

- Nitrogen gas from the cryofracture operation;
- Ventilation gases from the ERHs, PRHs, and MPF;
- Ventilation gases from the agent hydrolysis system; and

**TABLE 5.13 Estimated Total Wastes Generated during Construction of a Neutralization/SCWO Facility at BGAD**

Waste Category	Quantity
Hazardous solids	90 yd <sup>3</sup>
Hazardous liquids	37,000 gal
Nonhazardous solids	
Concrete <sup>a</sup>	210 yd <sup>3</sup>
Steel <sup>b</sup>	36 tons
Other <sup>c</sup>	1,700 yd <sup>3</sup>
Nonhazardous liquids	
Sanitary <sup>d</sup>	5.3E+06 gal
Other	2.4E+06 gal

<sup>a</sup> Amount of concrete (nonhazardous solid) waste was estimated by assuming that 0.65% of concrete usage is spoilage.

<sup>b</sup> Amount of steel waste stream was estimated as 0.5% of the steel requirement on the basis of a report by Lawrence National Laboratory and others (LLNL et al. 1997).

<sup>c</sup> Amount of other stream estimated as eight times the concrete stream on the basis of LLNL et al. (1997).

<sup>d</sup> Amount of sanitary waste was estimated on the basis of the total construction workforce.

**TABLE 5.14 Inventory and Estimated Processing Time for Neutralization/SCWO of ACW Stored at BGAD**

Munition	Quantity	Agent	Processing Rate (no. of munitions/h)	Processing Time		Changeover (weeks)	Total (weeks)
				Hours	Weeks <sup>a</sup>		
155-mm projectile, M110	15,492	H	80	194	2.7	0.0	2.7
155-mm projectile, M121A1	12,816	VX	80	160	2.2	6.0	8.2
8 in. projectile, M246	3,977	GB	20	199	2.8	6.0	8.8
Rocket, M55	51,716	GB	20	2,586	35.9	2.0	37.9
Rocket, M55	17,733	VX	20	887	12.3	2.0	14.3
Total	101,734			4,025	55.9	16.0	71.9

<sup>a</sup> Estimated by assuming 6-days-per-week operations and 12 hours per day.

**TABLE 5.15 Estimated Utilities Consumed during Destruction of ACW at the Neutralization/SCWO Facility at BGAD**

Utility	Average Daily Consumption	Peak Consumption	Annual Consumption
Process water <sup>a</sup>	23,000 gal/d	700 gal/min	6,300,000 gal/yr <sup>b</sup>
Potable water <sup>a</sup>	17,500 gal/d	180 gal/min	6,400,000 gal/yr <sup>b</sup>
Fire water <sup>a</sup>	NA <sup>c</sup>	3,000 gal/min	NA
Sanitary sewer <sup>a</sup>	20,650 gal/d	395 gal/min	7,540,000 gal/yr <sup>b</sup>
Natural gas	190,000 scf/d	15,000 scf/h	52,000,000 scf/yr <sup>d</sup>
Fuel oil	962 gal/d	406 gal/h	48,000 gal/yr <sup>e</sup>
Electricity	163 MWh	8.0 MW	59.6 GWh <sup>b,f</sup>

<sup>a</sup> Assumed to be similar to incineration because the number of operations and maintenance personnel and land area are unchanged from incineration.

<sup>b</sup> Based on 365 days of operation per year.

<sup>c</sup> NA = not applicable.

<sup>d</sup> Based on 276 days of operation per year.

<sup>e</sup> Based on 600 hours of operations per year.

<sup>f</sup> Based on an average power rating of 80%.

Source: PMCD (1998a).

**TABLE 5.16 Estimated Raw Materials Consumed Annually during Normal Neutralization/SCWO Operations at BGAD, Mustard Agent Processing**

Material	Average Daily Consumption (lb/d)	Annual Consumption (tons/yr) <sup>a</sup>
LN <sub>2</sub>	79,700	643
Liquid oxygen (LOX)	84,350	680
Water in caustic solution	17,600	142
NaOH	14,600	117
Phosphoric acid (H <sub>3</sub> PO <sub>4</sub> )	231	2.0
Kerosene for SCWO	16,100	130
Air for SCWO and HDC	77	0.6

<sup>a</sup> Estimated on the basis of a nominal campaign length of 16 days.

Source: Mitretek (2001b).

**TABLE 5.17 Estimated Raw Materials Consumed Annually during Normal Neutralization/SCWO Operations at BGAD, Nerve Agent Processing**

Material	Average Daily Consumption (lb/d)	Annual Consumption (tons/yr) <sup>a</sup>
LN <sub>2</sub>	5,800	800
LOX	32,000	4,400
Water in caustic solution	14,500	2,000
NaOH	12,900	1,780
Phosphoric acid (H <sub>3</sub> PO <sub>4</sub> )	8,300	1,200
Kerosene for SCWO	5,800	800
Air for SCWO and HDC	14,500	2,000

<sup>a</sup> Estimated on the basis of 276 operating days per year (campaign length of 319 days).

Source: Mitretek (2001b).

**TABLE 5.18 Transportation Data for Raw Materials for Neutralization/SCWO Processing of ACW Containing Mustard Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	LN <sub>2</sub>	LOX	H <sub>3</sub> PO <sub>4</sub>	Kerosene
Physical form	Liquid	Liquid	Liquid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	N <sub>2</sub> /-321°F, 1 atm	O <sub>2</sub> /-297°F, 1 atm	H <sub>3</sub> PO <sub>4</sub> / ambient	Kerosene/ ambient
Packaging					
Type	55-gal drum	5,400-gal tanker truck	4,000-gal tanker truck	55-gal drum	5,500-gal tank truck
Container volume (ft <sup>3</sup> )	7.35	722	535	7.35	735
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	NA <sup>a</sup>	NA	50	NA
Material weight (lb) <sup>b</sup>	700	43,720	38,080	774	39,020
Chemical content (wt%)	50% NaOH	100% N <sub>2</sub>	100% O <sub>2</sub>	100% H <sub>3</sub> PO <sub>4</sub>	NA
Shipments					
Average weight (tons/yr)	116.6	642.9	680.6	1.9	130.2
Average volume (ft <sup>3</sup> /yr)	2,478	21,232	19,114	36	4,908
Packages/yr	338	30	36	5	7
Packages/shipment	48	1	1	48	1
Shipments/yr	8	30	36	1	7
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Truck

<sup>a</sup> NA = not applicable.

<sup>b</sup> Based on Mitretek (2001b).

- Gases from the agent hydrolysate and energetics/dunnage hydrolysate SCWO systems.

These gases would be vented through scrubbers to the facility ventilation system where they pass through carbon filters prior to release to the atmosphere. Handling and disposal of process residue in accordance with the provisions of RCRA are expected to result in little potential for significant adverse impacts on air quality. Emissions from vehicles and combustion of natural gas and liquefied petroleum gas (LPG) are regulated by the U.S. Environmental Protection Agency (EPA) and the State of Kentucky and are expected to result in little potential for significant adverse impacts on air quality. Dust emissions also would be controlled during operations.

**TABLE 5.19 Transportation Data for Raw Materials for Neutralization/SCWO Processing of ACW Containing Nerve Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	LN <sub>2</sub>	LOX	H <sub>3</sub> PO <sub>4</sub>	Kerosene
Physical form	Liquid	Liquid	Liquid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	N <sub>2</sub> /-321°F, 1 atm	O <sub>2</sub> /-297°F, 1 atm	H <sub>3</sub> PO <sub>4</sub> / ambient	Kerosene/ ambient
Packaging					
Type	55-gal drum	5,400-gal tanker truck	4,000-gal tanker truck	55-gal drum	5,500-gal tank truck
Container volume (ft <sup>3</sup> )	7.35	721.87	534.72	7.35	735.24
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	NA <sup>a</sup>	NA	50	NA
Material weight (lb) <sup>b</sup>	700	43,720	38,080	774	39,020
Chemical content (wt%)	50% NaOH	100% N <sub>2</sub>	100% O <sub>2</sub>	100% H <sub>3</sub> PO <sub>4</sub>	NA
Shipments					
Average weight (tons/yr)	1,778.8	804.9	4,415.6	1,150.7	806.6
Average volume (ft <sup>3</sup> /yr)	37,800	26,585	124,010	21,878	30,402
Packages/yr	5,142	37	232	2,976	42
Packages/shipment	48	1	1	48	1
Shipments/yr	108	37	232	62	42
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Truck

<sup>a</sup> NA = not applicable.

<sup>b</sup> Based on Mitretek (2001b).

The neutralization/SCWO process would be required to meet RCRA and any other applicable environmental requirements and would operate under permit. The process would be required to destroy agent to a DRE of 99.9999% and to meet agent emission limits as established by the U.S. Army Surgeon General (ASG). Other emissions, including metals and HCl, would be regulated in accordance with the RCRA permit. The operation would also be required to meet air pollution control requirements for conventional pollutants, such as CO, SO<sub>2</sub>, and opacity.

All ventilation air would be processed through carbon filtration units before being released to the atmosphere. Facility effluent release points would include gaseous releases to the environment. Table 5.20 summarizes the characterization of the facility effluent air release points.

**TABLE 5.20 Stack Parameters for Neutralization/SCWO at BGAD<sup>a</sup>**

Installation or Emission Point	Physical Stack Height (ft)	Stack Exit Diameter (ft)	Stack Exit Gas Flow (acfm)	Stack Exit Gas Velocity (ft/s)	Stack Exit Gas Temp (°F)	Stack Location <sup>b</sup>
Process steam boiler I <sup>b,c</sup>	70	2	13,520	71.73	325	Near southwest corner of PUB
Process steam boiler II <sup>b,c</sup>	70	2	13,520	71.73	325	Near southwest corner of PUB
Process steam boiler III <sup>b,c</sup>	70	2	13,520	71.73	325	Near southwest corner of PUB
Diesel generator exhaust I <sup>b</sup>	47	0.67	6,765	323	925	Near northwest corner of PMB
Diesel generator exhaust II <sup>b</sup>	47	0.67	6,765	323	925	Near northwest corner of PMB
Filter farm stack <sup>d</sup>	120	6	96,000	56.59	77	Center of structure
SCWO stack <sup>d</sup>	80	2.5	12,000	40.74	77	NA, center of structure assumed

<sup>a</sup> Abbreviations: NA = not available, PMB = Personnel and Maintenance Building, PUB = Process Utilities Building.

<sup>b</sup> Information on the stack characteristics for neutralization/SCWO was unavailable; characteristics similar to neutralization/biotreatment were assumed (Parsons/Allied Signal 1999).

<sup>c</sup> Stack exit gas flow for the process steam boiler taken from Parsons/Allied Signal (1999) and modified to take into account the annual average natural gas consumption rate of 501,100 scf/d for neutralization/SCWO.

<sup>d</sup> Stack characteristics similar to those at Newport, Indiana, assumed (PMCD 1999).

Table 5.21 summarizes the criteria pollutant emission rates during operations, as estimated on the basis of the annual fuel consumption rates given in Table 5.15 and normal SCWO operations. Daily emissions can be estimated from the hourly rates, assuming 12 operating hours per day.

Small amounts of organic and metallic compounds would be emitted from the combustion of natural gas during normal boiler operation and from the combustion of fuel oil during emergency diesel generator operation. Tables 5.22 and 5.23 summarize the emission rates of toxic air pollutants (TAPs) from the process boiler and from the emergency diesel generator, respectively.<sup>60</sup> These rates were estimated on the basis of the annual fuel consumption rates

<sup>60</sup> Many of the TAPs that would be emitted from the pilot-test facility would be hazardous air pollutants (HAPs), as defined in Section 112 of the CAA, Title III. The term TAP is broader in that it includes some pollutants that are not HAPs.

**TABLE 5.21 Estimated Hourly and Annual Criteria Pollutant Emission Rates during Normal Neutralization/SCWO Operations at BGAD**

Potential Pollutant	Process Steam Boiler Stack <sup>a</sup>		Diesel Generator Exhaust Stack <sup>b</sup>		SCWO Stack <sup>c</sup>	
	lb/h	tons/yr	lb/h	tons/yr	lb/h	tons/yr
CO	1.3	2.18	10.4	3.12	0	0
NO <sub>x</sub>	2.12	3.64	48.4	14.50	0	0
SO <sub>2</sub>	0.01	0.02	32.0	0.95	0	0
PM <sub>10</sub>	0.12	0.20	3.4	1.02	0	0
HC	0.09	0.14	4.0	1.18	0	0
N <sub>2</sub> O <sup>d</sup>	0.0	0.00	0.0	0	139	146.1
H <sub>2</sub> <sup>d</sup>	0.0	0.00	0.0	0	33	37.4

<sup>a</sup> Estimated on the basis of the utility requirements listed in Table 5.15.

<sup>b</sup> Based on 600 hours of operations per year.

<sup>c</sup> Operation similar to neutralization/biotreatment assumed.

<sup>d</sup> Based on Table 4.5.1 of General Atomics (1999).

shown in Table 5.15 and with Factor Information Retrieval (FIRE) 6.22 emission factors for large wall-fired boilers with greater than 100 MMBtu/h of heat input and for reciprocating diesel generators (EPA 2000a). Daily emissions can be estimated from the hourly rates, assuming 12 operating hours per day.

The volume percent of hydrogen in the air effluent from the SCWO stack during nerve agent processing is estimated to be approximately 8% (Mitretek 2001b), which is within the flammable range of 4 to 75% for hydrogen. A series of malfunctions could potentially cause an ignition source to be present and rupture the off-gas treatment system (i.e., a process-related upset). Exhaust systems must be designed to minimize this hazard.

The neutralization/SCWO facility at BGAD would be equipped with building ventilation systems that would discharge, to the atmosphere, indoor air from the Munitions Demilitarization Building (MDB) process area, the Laboratory Building, and the Personnel and Maintenance Building through the filter farm stack. Of the three ventilation systems, only the indoor air from the MDB process area would be potentially exposed to chemical agents during operations.

To estimate the maximum potential emissions of chemical agents, only the MDB process area was considered to be a significant potential source. The filter systems would be designed to remove chemical agents from the ventilation air streams to levels below the allowable stack concentrations that have been recommended by the U.S. Department of Health and Human



**TABLE 5.22 Estimated Hourly and Annual TAP Emission Rates during Normal Boiler Operations for Neutralization/SCWO at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr) <sup>b</sup>
2-Methylnaphthalene	3.8E-07	1.2E-03
3-Methylchloranthrene	2.9E-08	9.4E-05
Acenaphthene	2.9E-08	9.4E-05
Acenaphthylene	2.9E-08	9.4E-05
Anthracene	3.8E-08	1.2E-04
Arsenic	3.2E-06	1.0E-02
Barium	7.0E-05	2.3E-01
Benz(a)anthracene	2.9E-08	9.4E-05
Benzene	3.3E-05	1.1E-01
Benzo(a)pyrene	1.9E-08	6.2E-05
Benzo(b)fluoranthene	2.9E-08	9.4E-05
Benzo(g,h,i)perylene	1.9E-08	6.2E-05
Benzo(k)fluoranthene	2.9E-08	9.4E-05
Beryllium	1.9E-07	6.2E-04
Butane	3.3E-02	1.1E+02
Cadmium	1.7E-05	5.7E-02
Chromium	2.2E-05	7.3E-02
Chrysene	2.9E-08	9.4E-05
Cobalt	1.3E-06	4.4E-03
Copper	1.3E-05	4.4E-02
Dibenzo(a,h)anthracene	1.9E-08	6.2E-05
Dichlorobenzene	1.9E-05	6.2E-02
Dimethylbenz(a)anthracene	2.5E-07	8.3E-04
Ethane	4.9E-02	1.6E+02
Fluoranthene	4.8E-08	1.6E-04
Fluorene	4.4E-08	1.5E-04
Formaldehyde	1.2E-03	3.9E+00
Hexane(n)	2.9E-02	9.4E+01
Indeno(1,2,3-cd)pyrene	2.9E-08	9.4E-05
Lead	7.9E-06	2.6E-02
Manganese	6.0E-06	2.0E-02
Mercury	4.1E-06	1.4E-02
Molybdenum	1.7E-05	5.7E-02
Naphthalene	9.7E-06	3.2E-02
Nickel	3.3E-05	1.1E-01
Pentane(n)	4.1E-02	1.4E+02
Phenanthrene	2.7E-07	8.8E-04
Propane	2.5E-02	8.3E+01
Pyrene	7.9E-08	2.6E-04
Selenium	3.8E-07	1.2E-03
Toluene	5.4E-05	1.8E-01
Vanadium	3.6E-05	1.2E-01

<sup>a</sup> Emission factors from EPA (2000a).

<sup>b</sup> This system of exponential notation is equivalent to  $N \times 10^{-x}$ ; for example, 4.4E-03 equals  $4.4 \times 10^{-3}$ .

**TABLE 5.23 Estimated Hourly and Annual TAP Emission Rates during Emergency Diesel Generator Operations for Neutralization/SCWO at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
Acenaphthene	3.1E-07	1.9E-04
Acenaphthylene	1.1E-06	6.7E-04
Acetaldehyde	1.7E-04	1.0E-01
Acrolein	2.0E-05	1.2E-02
Aldehydes	1.5E-02	9.2E+00
Anthracene	4.1E-07	2.5E-04
Benzene	2.0E-04	1.2E-01
Benzo (a) anthracene	3.7E-07	2.2E-04
Benzo (a) pyrene	4.1E-08	2.5E-05
Benzo (b) fluoranthene	2.2E-08	1.3E-05
Benzo (g,h,i) perylene	1.1E-07	6.4E-05
Benzo (k) fluoranthene	3.4E-08	2.0E-05
1,3-Butadiene	8.6E-06	5.1E-03
Chrysene	7.8E-08	4.6E-05
Dibenzo(a,h) anthracene	1.3E-07	7.7E-05
Fluoranthene	1.7E-06	1.0E-03
Fluorene	6.4E-06	3.8E-03
Formaldehyde	2.6E-04	1.6E-01
Indeno(1,2,3-cd)pyrene	8.2E-08	4.9E-05
Isomers of xylene	6.3E-05	3.7E-02
Mercury	6.6E-08	4.0E-05
Naphthalene	1.9E-05	1.1E-02
Phenanthrene	6.5E-06	3.9E-03
Polycyclic aromatic hydrocarbons (PAHs)	3.7E-05	2.2E-02
Propylene	5.7E-04	3.4E-01
Pyrene	1.0E-06	6.3E-04
Toluene	9.0E-05	5.4E-02

<sup>a</sup> Emission factors from EPA (2000a).

Services, Centers for Disease Control (53 *Federal Register* 8504 – 8507, March 15, 1988). Also, a negative pressure would be maintained at all times in the MDB after initiation of hot operations to inhibit the release of chemical agents. Table 5.24 gives the potential chemical agent emission rates, assuming that the chemical agent concentrations in the air discharged from the filter farm stack would be 20% of the recommended allowable stack concentrations (i.e., the level of quantification of the ventilation exhaust chemical agent monitors.) These emission calculations were based on operations time (12 hours per day, 276 days per year).

**TABLE 5.24 Estimated Maximum Hourly and Annual Agent Emission Rates from the Filter Farm Stack for Neutralization/SCWO at BGAD**

Chemical Agent	Emission Factor (mg/m <sup>3</sup> ) <sup>a</sup>	Stack Exit Gas Flow (acfm) <sup>b</sup>	Hours of Operation per Year <sup>c</sup>	Stack Emission Rate	
				lb/h	tons/yr <sup>d</sup>
GB	0.00006	96,000	2,785	2.2E-05	3.0E-05
VX	0.00006	96,000	1,047	2.2E-05	1.1E-05
HD	0.006	96,000	194	2.2E-03	2.1E-04

<sup>a</sup> Based on the monitor level of quantification, which is 20% of the allowable stack concentration recommended for each chemical agent in Title 53, Parts 8504–8507, *Code of Federal Regulations* (53 CFR 8504–8507)

<sup>b</sup> Filter farm stack exit flow based on building ventilation for the MDB.

<sup>c</sup> Hours of operations based on the assumption that each pilot plant operates at the design throughputs specified in CBDCOM (1997).

<sup>d</sup> Estimate based on the number of hours of operation.

Tables 5.25 and 5.26 provide the estimated emission rates of TAPs during operations from the SCWO stack for mustard agent and nerve agents, respectively. Annual emission rates can be estimated from the daily values, assuming 16 days of actual operations per year for mustard agent (Table 5.25) and 276 days of operations per year for nerve agent (Table 5.26).

Emissions from operations worker commuter vehicles were estimated on the basis of the assumption that an average of 721 automobiles (1 car per operations worker) would be added to the area of the site and that each worker would drive an average of 20 mi (32 km) to the site. Table 5.27 gives the annual emission estimates due to the increased traffic.

**Liquid Wastes.** As indicated previously, brine liquids from the SCWO units would be sent to the BRA where they would be dried to form brine salts. Other liquids, such as spent decontamination solutions and laboratory wastes, would be fed to the SCWO units. Domestic sewage is the only major liquid effluent expected to be generated at the destruction facility. Small amounts of hazardous liquids could be generated from chemical makeup and reagents for support activities; the quantities are expected to be minor compared with those for domestic sewage (sanitary waste). Sanitary waste would be managed on-site.

**Solid Wastes.** The major process solid residuals expected from the neutralization/SCWO operation include the following:

- Brine salts from treatment of the SCWO effluent,
- Decontaminated (5X condition) scrap metal from the HDCs and the inductively heated MPF, and

**TABLE 5.25 Estimated TAP Emission Rates from the SCWO Stack during Neutralization/SCWO of ACW Containing Mustard Agent at BGAD<sup>a</sup>**

Compound <sup>b</sup>	Emission Rate (lb/d)	Compound <sup>b</sup>	Emission Rate (lb/d)
Acetaldehyde	2.7E-11	Methyl ethyl ketone/butyraldehydes	8.7E-12
Antimony	3.5E-11	Nickel	2.6E-10
Arsenic	1.3E-11	Particulates	1.4E-08
Beryllium	2.6E-12	Phosphorus	4.1E-09
Cadmium	2.6E-12	Selenium	1.3E-11
Chromium	7.6E-11	Total HpCDF	3.7E-20
Cobalt	1.8E-11	Ethyl benzene	2.4E-10
Formaldehyde	3.5E-11	p-Creosol (4-Methylphenol)	1.8E-11
Lead	4.2E-11	m-Xylene	2.1E-10
Manganese	6.6E-11	Total TCDD	2.5E-16

<sup>a</sup> Annual emissions can be estimated on the basis of the assumption that the nominal campaign length is 16 days.

<sup>b</sup> Abbreviations: HpCDF = heptachlorodibenzo-p-furan, TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin.

**TABLE 5.26 Estimated TAP Emission Rates from the SCWO Stack during Neutralization/SCWO of ACW Containing Nerve Agent at BGAD<sup>a</sup>**

Compound	Emission Rate (lb/d)	Compound	Emission Rate (lb/d)
Acetaldehyde	9.5E-11	Manganese	1.1E-10
Antimony	7.8E-12	Mercury	9.7E-12
Arsenic	2.4E-12	Methyl ethyl ketone/butyraldehydes	2.5E-12
Beryllium	4.8E-13	Naphthalene	8.1E-14
Cadmium	1.2E-11	Nickel	5.3E-10
Chromium	1.1E-10	Particulates	9.1E-09
Cobalt	1.4E-11	Phosphorus	2.9E-09
Formaldehyde	1.2E-11	Selenium	1.9E-11
Lead	1.2E-10		

<sup>a</sup> Annual emissions can be estimated on the basis of the assumption that there are 276 days of operations per year.

**TABLE 5.27 Estimated Emissions from Worker Commuter Vehicles for Neutralization/SCWO Operations at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Emission Rate (tons/yr)
HC	199,000	1.16	20	16.4
CO	199,000	11.38	20	160.7
NO <sub>x</sub>	199,000	0.73	20	10.3
SO <sub>2</sub>	199,000	0.12	20	1.7
PM <sub>10</sub>	199,000	0.055	20	0.78

<sup>a</sup> Number of auto round trips to the operation site estimated on the basis of the annual operating workforce and an assumption of 276 days of operation per year.

<sup>b</sup> Emission factors determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub>, and EPA PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

- Decontaminated (5X condition) salts removed from the energetics hydrolysates and thermally treated in the inductively heated MPF.

The effluent from the SCWO unit would be sent to an evaporator that produces a filter cake with about 70% solids. The water content is bound as water of hydration; free-standing liquid is not expected (NCD 1998b). The filter cake would be transported to an approved off-site hazardous waste treatment, storage, and disposal facility for additional treatment and/or ultimate disposal. Table 5.28 provides information on the chemical composition of the brine salts (filter cake).

Nonhazardous scrap metal (5X condition) from the munition bodies would be sold to a scrap dealer or smelter for reuse if approved by the regulatory authority (see Table 5.29). However, if it proves necessary, these metals could be disposed of off-site in a nonhazardous waste landfill or in a RCRA-permitted hazardous waste landfill. Table 5.30 gives the amounts of other process-related wastes.

Nonprocess waste streams would include decon solution, DPE suits, spent carbon, waste oils, trash, debris, and spent hydraulic fluid, which are assumed to be potentially agent-contaminated and that would be processed in the dunnage/waste processing system. After this processing, the only streams with a significant solid residue would be the decon solution (containing NaOH and sodium hypochlorite [NaOCl]) and miscellaneous metal parts from equipment operation. Tables 5.31 and 5.32 provide information on the daily and annual generation rates of treated, nonprocess wastes for ACW containing mustard agent and nerve agent, respectively.

**TABLE 5.28 Estimated Generation Rates of Brine Salts from Neutralization/SCWO at BGAD To Be Sent Off-Site for Land Disposal**

Compound	Generation Rate (lb/d)		Compound	Generation Rate (lb/d)	
	Mustard Agent	Nerve Agent		Mustard Agent	Nerve Agent
1,2,3,4,6,7,8-HpCDD	1.3E-09	0.0E+00	Manganese	7.4E-02	4.3E-01
1,2,3,4,6,7,8-HpCDF	1.4E-10	0.0E+00	Mercury	1.4E-04	2.3E-03
2-Butanone	6.9E-04	3.8E-04	Methylene chloride	0.0E+00	5.6E-04
Acetaldehyde	1.3E-02	7.5E-02	Molybdenum	1.7E+00	2.6E+00
Acetone	0.0E+00	1.7E-03	Naphthalene	1.7E-04	0.0E+00
Aldol condensate	0.0E+00	5.6E-04	Nickel	4.1E+00	9.3E+01
Aluminum	3.8E-01	3.4E+01	Nitrate	1.5E+00	5.1E+01
Antimony	2.2E-02	1.2E-01	Nitrite	1.7E+00	8.7E+00
Arsenic	0.0E+00	3.0E-01	OCDD	5.7E-09	0.0E+00
Barium	7.3E-03	0.0E+00	Phenol	1.0E-04	1.9E-04
Bis(2-ethylhexyl)phthalate	1.1E-03	3.0E-03	Potassium	2.5E-01	4.5E-01
Bromomethane	0.0E+00	7.3E-03	Selenium	3.3E-03	0.0E+00
Cadmium	2.6E-02	1.7E-02	Silane	0.0E+00	2.9E-02
Calcium	1.7E-01	1.7E+00	Siloxane	6.9E-03	2.1E-02
Calcium silicate	0.0E+00	8.8E+00	Silver	4.7E-03	7.4E-02
Chloride	1.6E+02	0.0E+00	Sodium chloride	6.8E+03	0.0E+00
Chloromethane	5.2E-04	9.9E-03	Sodium fluoride	0.0E+00	5.5E+02
Chromium	1.1E+00	2.1E+01	Sodium phosphate	3.9E+02	1.7E+04
Cobalt	1.6E-02	1.4E-01	Sodium sulfate	1.7E+04	4.1E+02
Copper	6.9E-01	5.5E+00	Sulfide, reactive	8.6E-01	1.5E+00
Cyclohexanone	5.2E-02	2.4E-02	TCDD	1.1E-09	0.0E+00
Di-n-butylphthalate	2.1E-04	7.0E-04	Thallium	0.0E+00	2.1E-01
Fluoride	0.0E+00	3.4E+02	Vanadium	3.6E-03	3.9E-02
Formaldehyde	5.5E-03	3.8E-02	Water in salt cake	3.6E+03	2.6E+03
Iron	2.1E+00	1.8E+01	Zinc	8.9E-01	3.3E+00
Lead	3.9E-03	2.3E+01	Total	2.8E+04	2.1E+04
Magnesium	1.9E-01	1.5E+00			

<sup>a</sup> Abbreviations: HpCDD = heptachlorodibenzo-p-dioxin, HpCDF = heptachlorodibenzo-p-furan, OCDD = octachlorodibenzo-p-dioxin, TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Annual waste generation rates can be estimated from the daily values, assuming 16 days of actual operations per year for mustard agent processing and 276 days of operations per year for nerve agent processing (since the total campaign length of 319 days for nerve agent processing exceeds 276 days).

The above waste streams may be shipped from the on-site facility to off-site locations. Tables 5.33 and 5.34 provide transportation data for annual shipment of these waste streams during processing of mustard agent and nerve agent, respectively. Table 5.35 provides transportation data for nonprocess solid wastes from neutralization/SCWO. It was assumed that all wastes would be packaged in 55-gal (208-L) drums prior to off-site shipment.

**TABLE 5.29 Estimated Generation Rates of 5X Solids from Neutralization SCWO at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)	
	Mustard Agent	Nerve Agent
Steel/iron	7.7E+04	1.1E+04
Aluminum	5.8E+01	8.9E+02
Copper	1.8E+03	9.0E+01
Zinc	3.2E+02	8.6E+00
Glass fiber	0.0E+00	8.4E+02
Total	7.9E+04	1.2E+04

**TABLE 5.30 Estimated Generation Rates of Other Solid Wastes from Neutralization/SCWO at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Other Wastes	Generation Rate (lb/d)	
	Mustard Agent	Nerve Agent
Metal from dunnage	1.0E+03	1.5E+02
Al(OH) <sub>3</sub> <sup>a</sup>	0.0E+00	8.8E+03

<sup>a</sup> A zero effluent rate was estimated because the ACW inventory at BGAD does not include aluminum oxides (glass).

**TABLE 5.31 Calculated Quantities of Solid Residues from Nonprocess Wastes from Neutralization/SCWO of ACW Containing Mustard Agent at BGAD**

Waste Type	Inlet Waste Composition	Treatment Process	Product	Daily Quantity (lb/d)	Annual Quantity (tons/yr)
Decon solution	18 wt% NaOH, NaOCl <sup>a</sup>	SCWO	Brine, 15% water	1,200	9.7
Miscellaneous metal parts	Nonmunition scrap metal	MPF	100% Metal	380	3.1
Total				1,600	13

<sup>a</sup> Source: PMCD (1998a).

**TABLE 5.32 Calculated Quantities of Solid Residues from Nonprocess Wastes from Neutralization/SCWO of ACW Containing Nerve Agent at BGAD**

Waste Type	Inlet Waste Composition	Treatment Process	Product	Daily Quantity (lb/d)	Annual Quantity (tons/yr)
Decon solution	18 wt% NaOH, NaOCl <sup>a</sup>	SCWO	Brine, 15% water	350	48
Miscellaneous metal parts	Nonmunition scrap metal	MPF	100% Metal	110	15
Total				460	63

<sup>a</sup> Source: PMCD (1998a).

**TABLE 5.33 Transportation Data for Solid Wastes from Neutralization/SCWO of ACW Containing Mustard Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3
Transported materials			
Type/chemical	Brine salts – waste	5X Solids – waste	Other wastes
Physical form	Solid	Solid	Solid
Chemical composition/temperature, pressure	See Table 5.28	See Table 5.29	See Table 5.30
Packaging			
Type	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> /yr) <sup>a</sup>	7.35	7.35	7.35
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	50	50
Material weight (lb)	1,060	450	450
Chemical content (wt%)	See Table 5.28	See Table 5.29	See Table 5.30
Shipments			
Average weight (tons/yr) <sup>b</sup>	223	641	8
Average volume (ft <sup>3</sup> /yr) <sup>a</sup>	3,110	21,330	270
Packages/yr	423	2,902	37
Packages/shipment	36	48	48
Shipments/yr <sup>b</sup>	12	61	1
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Destination – facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the 5X solids would allow disposal in standard 55-gal drums.

<sup>b</sup> Estimated on the basis of a campaign length of 16 days.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.



**TABLE 5.34 Transportation Data for Solid Wastes from Neutralization/SCWO of ACW Containing Nerve Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3
Transported materials			
Type/chemical	Brine salts – waste	5X solids – waste	Other wastes
Physical form	Solid	Solid	Solid
Chemical composition/ temperature, pressure	See Table 5.28	See Table 5.29	See Table 5.30
Packaging			
Type	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> ) <sup>a</sup>	7.35	7.35	7.35
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	50	50
Material weight (lb)	740	450	450
Chemical content (wt%)	See Table 5.28	See Table 5.29	See Table 5.30
Shipments			
Average weight (tons/yr) <sup>b</sup>	2,787	1,719	1,229
Average volume (ft <sup>3</sup> /yr)	55,500	57,180	40,880
Packages/yr	7,549	7,778	5,561
Packages/shipment	48	48	48
Shipments/yr	158	163	116
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Destination – facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the solids would allow disposal in standard 55-gal drums.

<sup>b</sup> Estimated on the basis of 276 days of operations per year.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

Table 5.36 lists the type and quantity of nonhazardous (nonprocess) solid and liquid wastes that could be generated from facility operation. Waste generation rates are based on historic data on building size, utility requirements, and facility workforce.

#### 5.3.2.4 Activities

The PMACWA described activities for installation of the neutralization/SCWO system (PMACWA 1999a). The major phases of the project are shown in Table 5.37.

**TABLE 5.35 Transportation Data for Nonprocess Solid Wastes from Neutralization/SCWO of ACW Containing Mustard or Nerve Agent at BGAD**

Site	Mustard Agent	Nerve Agent
Transported materials		
Type/chemical	Nonprocess waste	Nonprocess waste
Physical form	Solid	Solid
Chemical composition/temperature, pressure	See Table 5.31	See Table 5.32
Packaging		
Type	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35
Certified by	DOT	DOT
Identifier	Varies	Varies
Container weight (lb)	50	50
Material weight (lb)	493	493
Chemical content (wt%)	See Table 5.31	See Table 5.32
Shipments		
Average weight (tons/yr)	13 <sup>a</sup>	63 <sup>b</sup>
Average volume (ft <sup>3</sup> /yr)	390	1,876
Packages/yr	54	256
Packages/shipment	48	48
Shipments/yr	2	6
Form of Transport/Routing		
Form of transportation	Truck	Truck
Destination – facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>

<sup>a</sup> Estimated on the basis of a campaign length of 16 days.

<sup>b</sup> Estimated on the basis of 276 days of operations per year.

<sup>c</sup> Depending on the results of the test for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

**TABLE 5.36 Estimated Annual Nonhazardous (Nonprocess) Waste Generated during Neutralization/SCWO Operations at BGAD**

Category	Solid (yd <sup>3</sup> )	Liquid (gal)
Nonhazardous (sanitary) wastes	NA <sup>a</sup>	4.6E+06
Nonhazardous (other) wastes <sup>b</sup>	1,800	NA
Recyclable wastes <sup>c</sup>	720	NA

<sup>a</sup> NA = not applicable.

<sup>b</sup> Nonhazardous (other) wastes include domestic trash and office waste.

<sup>c</sup> Recyclable wastes include paper, aluminum, etc., generated by the facility.

### 5.3.2.5 Uncertainties

As indicated previously, each of the individual technologies that form the neutralization/SCWO system has either been previously proven to be a successful technology or has been demonstrated by the PMACWA to be an acceptable technology for application at BGAD. However, demonstration testing focused on individual technologies and sometimes used less than full-scale units. In addition, although EDSs were conducted to evaluate the long-term adequacy of individual technologies, it was not possible to evaluate the long-term viability and performance of the entire, integrated treatment system. Thus, the primary uncertainty associated with neutralization/SCWO is that the entire, integrated treatment system with all its component units has not been assembled and tested. The pilot program, if implemented for this technology system, would be designed to evaluate overall operability and long-term performance.

### 5.3.3 NEUTRALIZATION/BIOTREATMENT

This description of the neutralization/biotreatment facility is based on the preliminary design information provided in Parsons/Allied Signal (1999). As indicated in that report, many of the estimates provided for facility design refer to the U.S. Army baseline incineration process, which indicates, in general, that the estimates are comparable to those associated with the baseline incineration process (Parsons/Allied Signal 1999). Thus, another of the primary sources of information for this section is the EIS for disposal of chemical agents and munitions stored at Pine Bluff Arsenal, Arkansas (PMCD 1997). That is the most recent EIS that the U.S. Army has completed for baseline incineration of chemical munitions.

**TABLE 5.37 Activities for  
Neutralization/SCWO at BGAD**

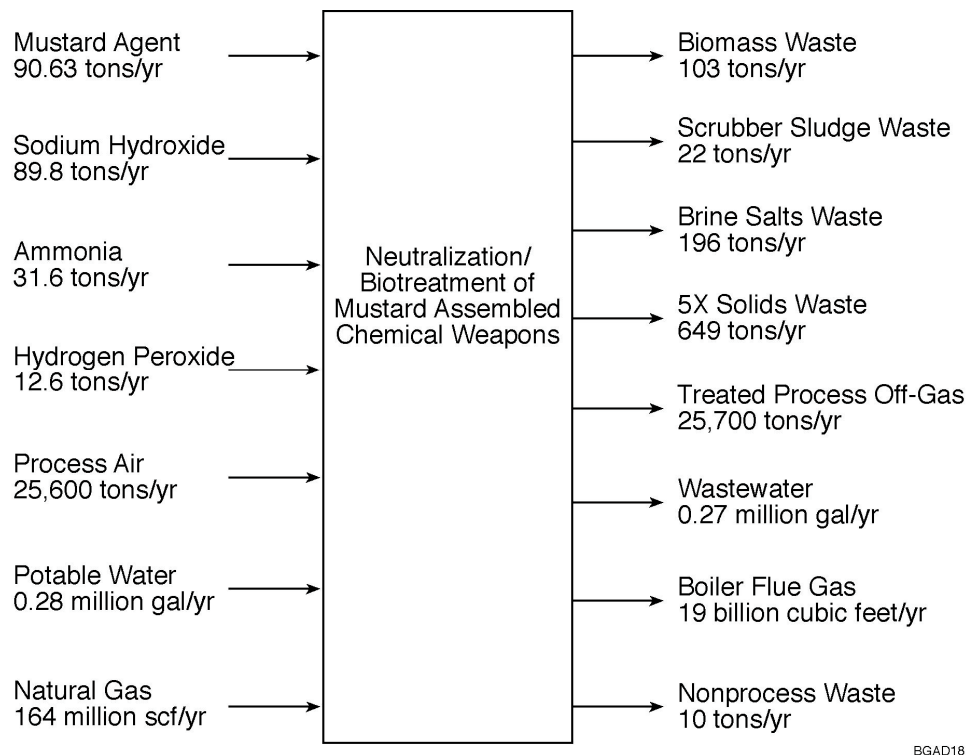
Key Milestones
EIS start
EDS testing start
Final EIS/ROD
Final design (65% completion)
RCRA Part B issued
MDB construction start
MDB construction finish
Systemization start (pilot train)
Systemization start (all trains)
Operations start
Operations finish

Source: PMACWA (1999a).

In addition, mass balance estimates, air emission estimates, and solid waste estimates for application of the neutralization/biotreatment technology at BGAD have been prepared (Mitretek 2001b). Air emissions and solid waste estimates for neutralization/biotreatment, as discussed below, are based on Mitretek inputs (Mitretek 2001b), along with appropriate assumptions on filtration systems and plant operations and schedule. Figure 5.31 provides an input/output material balance for the major streams for neutralization/biotreatment of ACW containing mustard agent.

Many of the figures and tables referred to in the facility description for this technology system contain estimates (e.g., emissions, resources consumed) associated with processing ACW with a specified agent; these estimates are given on an annual basis (e.g., tons/yr). In some cases, the estimates have been converted from other units (e.g., lb/d) by accounting for the number of days of operation required for processing a specific type of ACW. This time period is referred to as a campaign; a campaign is agent-specific. The values in many of the following figures and tables are based on the number of days in the campaign required to process ACW containing a specific agent. It was assumed that there are 276 operating days in a year. If the campaign is less than or equal to 276 days, annual quantities equal total quantities. If the campaign is greater than 276 days, quantities in the figures and tables are for 276 days of processing. In the latter case, the estimates provided are less than total quantities. Daily (or other) quantities may be obtained by adjusting for the number of days in the campaign.

Details provided in the following discussion on the neutralization/biotreatment facility are estimates.



**FIGURE 5.30 Input/Output Material Balance for Neutralization/Biotreatment of ACW Containing Mustard Agent at BGAD**

### 5.3.3.1 General Facility Description

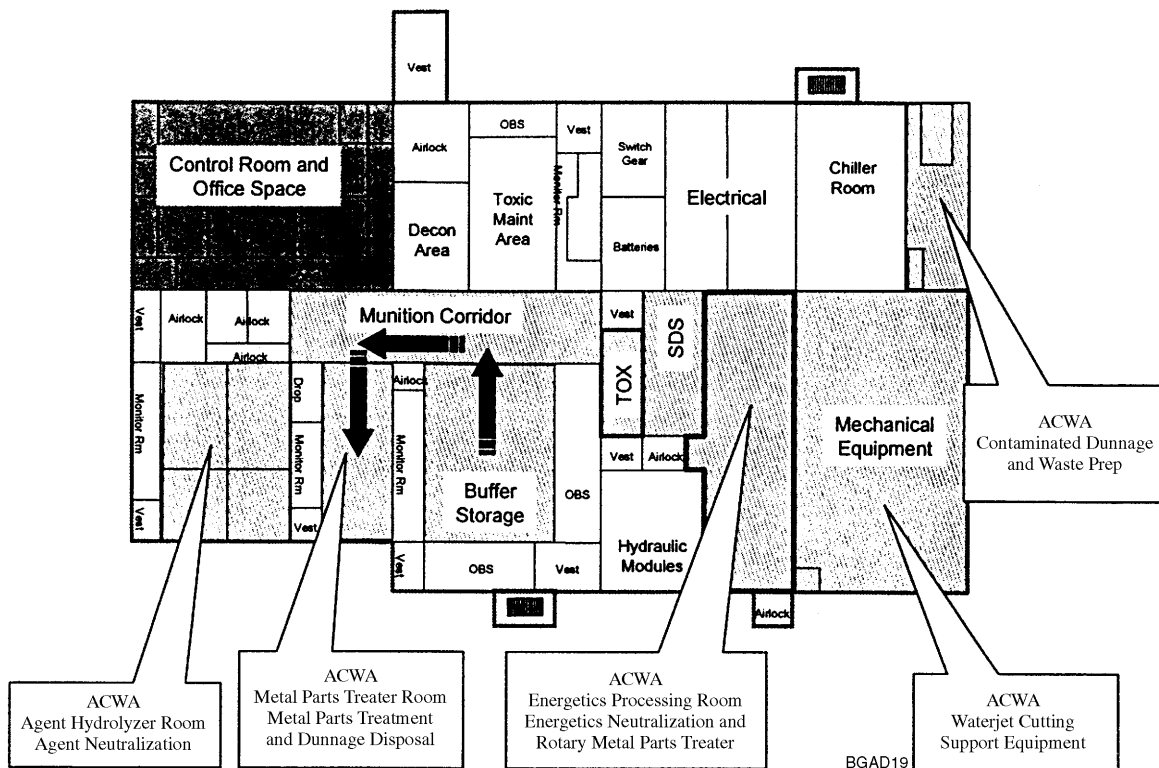
The neutralization/biotreatment process has been demonstrated for ACW containing mustard agent only. The inventory of ACW containing mustard agent at BGAD is relatively small. As indicated in the proceeding discussion, it would take only 16 days of operations to destroy the inventory of ACW containing mustard agent at BGAD. Because of the limited quantity of ACW containing mustard agent at BGAD, it is unlikely that a full-scale pilot facility that could process only mustard-agent-filled ACW would be constructed at BGAD. However, a less than full-scale pilot facility for these ACW is possible. While such a facility may be significantly smaller than full-scale, the size of the facility cannot currently be delineated; therefore a full-scale facility was assumed to simplify analysis and to allow for the consideration of multiple ACWA facilities under cumulative impacts.

The proposed neutralization/biotreatment facility is designed to fit into approximately the same space and general configuration as the baseline incineration process. Munitions access and disassembly, neutralization, and biotreatment operations have been substituted for incineration operations. The physical plant consists of a two-story building constructed of noncombustible materials with a concrete structural frame and a low-slope concrete roof.

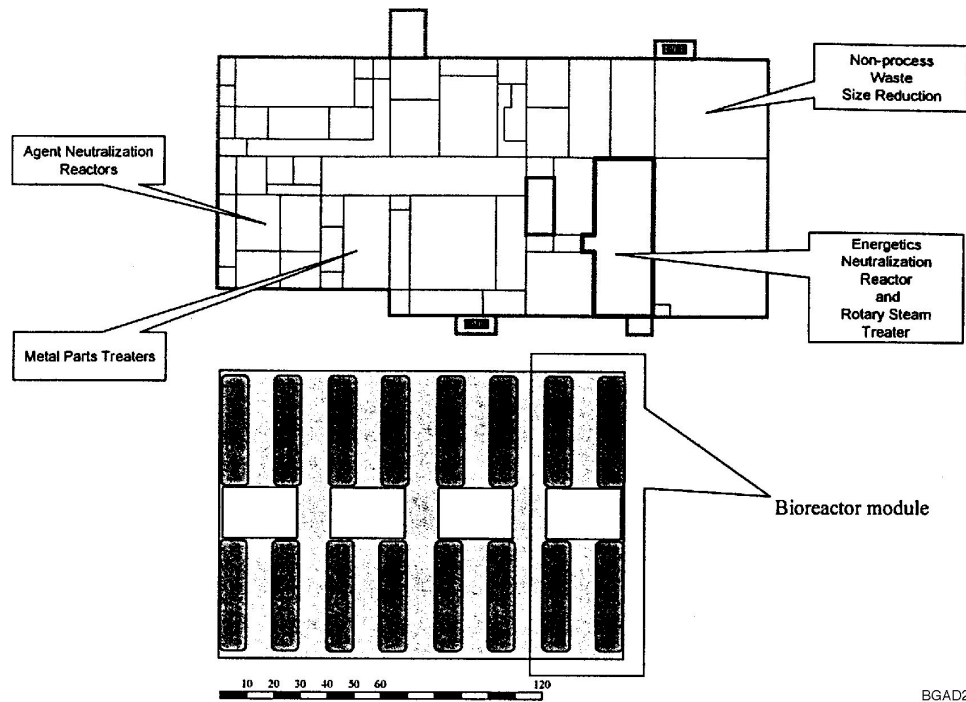
The site layout for neutralization/biotreatment is shown in Figures 5.32 through 5.34. Figure 5.32 shows the layout of the first floor, Figure 5.33 shows the layout of the second floor, and Figure 5.34 shows the layout of the biotreatment operation. The biotreatment units would be physically located outside the two-story building.

### 5.3.3.2 Construction Phase

The schedule for demilitarization of the stockpile at BGAD, although tentative, calls for construction of the selected alternative to begin following issuance of the EIS ROD and receipt of the RCRA and any other environmental permits, as necessary. It is anticipated that the construction schedule of the neutralization/ biotreatment facility would not differ significantly from that required for baseline incineration. Construction would take approximately 34 months (PMCD 1997), including a 2-month design and verification period. However, the PMACWA is investigating means of shortening the construction period.



**FIGURE 5.31 Layout of First Floor of Neutralization/Biotreatment Facility at BGAD**  
(Source: Parsons/Allied Signal 1999)



BGAD20

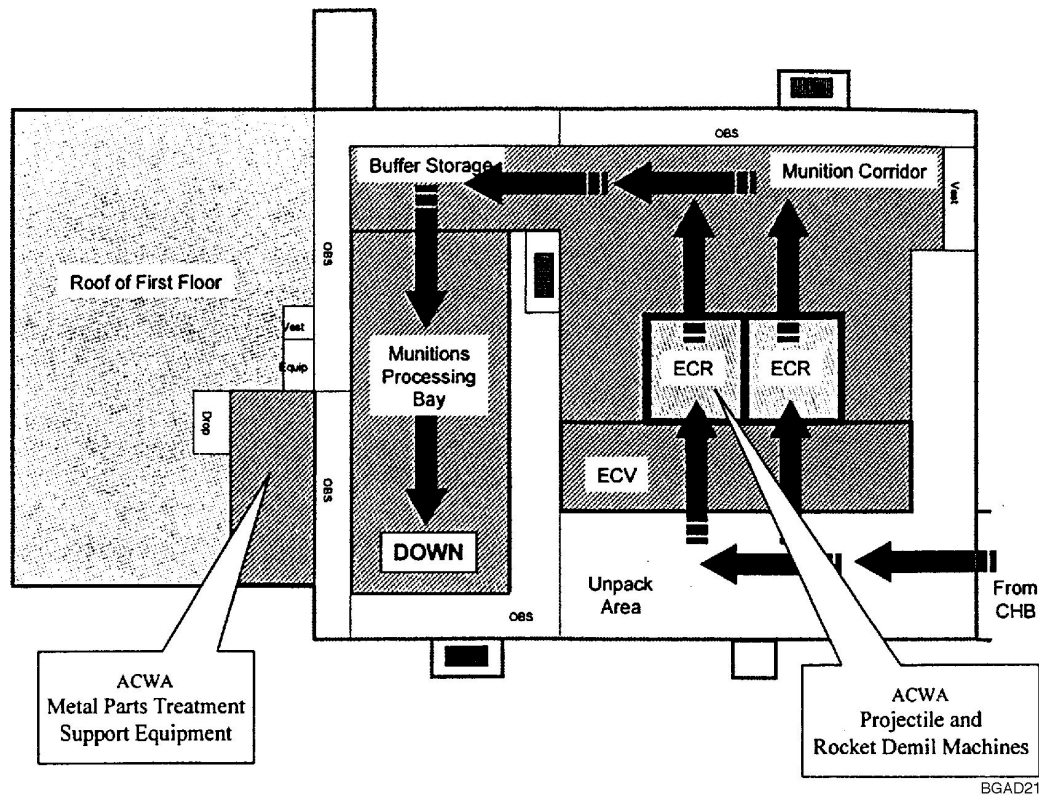
**FIGURE 5.32 Layout of Second Floor of Neutralization/Biotreatment Facility at BGAD**  
(Source: Parsons/Allied Signal 1999)

Construction of the disposal facility on the BGAD installation would result in vehicle exhaust emissions, fugitive dust, noise, destruction of wildlife habitat and native vegetation, increased employment, increased demand for public services, and occupational health hazards.

#### 5.3.3.2.1 Construction Inputs and Resource Requirements

The PMACWA has estimated that the capital cost for the neutralization/biotreatment process would be approximately 5% less than that required for construction of the baseline incineration system (PMACWA 1999a). Resources needed for facility construction include water, electricity, concrete, steel, liquid fuels, lumber, and industrial gases (e.g., propane). Table 5.38 provides an estimate of construction material consumption during facility construction.

The process equipment would be purchased from equipment vendors. Specialty materials, such as Inconel or Monel, do not appear to be required. However, the bioreactors may require specialty materials in the final design (PMACWA 1999a).



**FIGURE 5.33 Layout of the Biotreatment Operation of the Neutralization/Biotreatment Facility at BGAD (Source: Parsons/Allied Signal 1999)**

Table 5.39 provides an order of magnitude estimate of the number of shipments of construction materials to the site. The estimate does not include process equipment and related items; the number of shipments associated with these resources is expected to be small in comparison to the estimate of 5,000 total shipments.

An order-of-magnitude estimate of the emissions from construction delivery vehicles to the site is provided in Table 5.40, assuming a one-way trip distance of 20 mi (32 km) and delivery by heavy-duty diesel trucks. The actual trip distances would depend on a number of factors, including the availability of construction materials from local distributors and the distance of the site from local distributors.

### 5.3.3.2.2 Construction Workforce

The construction workforce is expected to steadily increase to a peak of about 780 FTEs near the midpoint of the construction period, and then to decrease steadily until construction is



**TABLE 5.38 Estimated Materials/Resources Consumed during Construction of a Neutralization/Biotreatment Facility at BGAD<sup>a</sup>**

Construction Material/Resource	Total Consumption	Peak Demand
Utilities		
Water <sup>b</sup>	8,000,000 gal	NA <sup>c</sup>
Electricity	46,000 MWh	2.3 MW
Solids		
Concrete	32,600 yd <sup>3</sup>	NA
Steel (structural and reinforcing)	6,400 tons	NA
Piping (all)	116,000 linear ft	NA
Liquids		NA
Fuel	2.4E+06 gal	NA
Gases		
Industrial gases (propane)	6,500 gal	NA

<sup>a</sup> All values are order-of-magnitude approximations of the actual values; more accurate values would require a detailed consideration of construction activities.

<sup>b</sup> The water requirement was estimated on the basis of DOE (1997), in which each FTE required 20 gal/d, and solidification required 26 lb per 100 lb of cement.

<sup>c</sup> NA = not applicable.

completed. The average number of construction workers is estimated to be approximately 390 FTEs. Assuming a 34-month construction period, approximately 1,100-FTE-years of effort would be expended during construction. Table 5.41 provides an estimate of the employment buildup by year during construction.

### 5.3.3.2.3 Construction Emissions and Waste Estimates

During the construction phase, fugitive emissions would consist mainly of dust and vehicle exhaust. Temporary, regional increases in atmospheric concentrations of CO, NO<sub>x</sub>, hydrocarbons, particulate matter, and SO<sub>x</sub> would result from the exhaust emissions of commuter vehicles, heavy construction vehicles, diesel generators, and other machinery and tools. Annual emissions of these pollutants would be small in comparison to de minimis levels typically used by regulators to determine whether an air quality permit or impact analysis is necessary.

**TABLE 5.39 Order-of-Magnitude Estimate of the Number of Truck Shipments of Construction Materials<sup>a</sup> for Construction of a Neutralization/Biotreatment Facility at BGAD**

Resource	Total Consumption	Truck Capacity	No. of Truck Shipments
Portland cement <sup>b</sup>	3,586 yd <sup>3</sup>	10 yd <sup>3</sup>	359
Gravel <sup>b</sup>	13,366 yd <sup>3</sup>	10 yd <sup>3</sup>	1,337
Sand <sup>b</sup>	8,476 yd <sup>3</sup>	10 yd <sup>3</sup>	848
Steel <sup>c</sup>	6,400 tons	21 tons	310
Asphalt paving <sup>d</sup>	1,200 tons	20 tons	60
Backfill <sup>e</sup>	12,400 yd <sup>3</sup>	10 yd <sup>3</sup>	1,240
Fuel <sup>f</sup>	2.4E+06 gal	9,000 gal	270
Total			4,424
Total (rounded up)			5,000

<sup>a</sup> The calculation did not include truck deliveries of process equipment and related items.

<sup>b</sup> Assumes that concrete is composed of 11% portland cement, 41% gravel, and 26% sand, and is shipped to the site in a standard 10-yd<sup>3</sup> end-dump truck.

<sup>c</sup> Assumes that the net payload for steel transport to the site is 42,000 lb.

<sup>d</sup> Assumes HMA is loaded into 20-ton capacity triaxle trucks for transport to the paving site.

<sup>e</sup> Assumes shipment is in standard 10-yd<sup>3</sup> end-dump trucks.

<sup>f</sup> Assumes shipment is in a DOT 406/MC-306 atmospheric pressure tank truck with a 9,000-gal capacity.

Emissions from construction vehicles are exempt from permit requirements. Nevertheless, vehicles and machinery would be equipped with standard pollution control devices to minimize air quality impacts.

Estimated criteria pollutant emissions from construction activities (not including emissions from delivery vehicles) are shown in Table 5.42. The emissions shown are based on the anticipated construction land disturbance and vehicle traffic (for dust particulate pollutants) and fuel and gas consumption. The column marked "Total" indicates the total amount of emissions that is estimated to occur over the entire construction period.

Emissions from construction worker commuter vehicles were estimated on the basis of the assumption that an average of 390 automobiles (1 car per construction worker) would be

**TABLE 5.40 Estimated Emissions from Delivery Vehicles during Construction of a Neutralization/Biotreatment Facility at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Construction Period (yr)	Emission Rate (tons/yr)
HC	5,000	2.12	20	2.8	0.3
CO	5,000	11.28	20	2.8	1.4
NO <sub>x</sub>	5,000	1.25	20	2.8	0.2
SO <sub>x</sub>	5,000	0.23	20	2.8	0.03
PM <sub>10</sub>	5,000	0.617	20	2.8	0.1

<sup>a</sup> The number of auto round trips to the construction site was estimated on the basis of the total number of deliveries.

<sup>b</sup> Emission factors were determined by using EPA modeling software MOBILE5b computer model (EPA 2000c) for HC, CO, and NO<sub>x</sub> and EPA PART5 model (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on (DOE 1997).

**TABLE 5.41 Estimated Number of Employees Needed by Year for Construction of a Neutralization/Biotreatment Facility at BGAD**

Employees	Year 1	Year 2	Year 3
Total craft workers	220	500	150
Construction management and support staff	60	130	40
Total	280	630	190

**TABLE 5.42 Estimated Criteria Pollutant Emissions during Construction of a Neutralization/Biotreatment Facility at BGAD**

Criteria Pollutant	Total (tons)	Annual (tons/yr)
CO	122	43
HC	51	18
NO <sub>x</sub>	182	64
SO <sub>x</sub>	12	4
Particulates	522	184

**TABLE 5.43 Estimated Criteria Pollutant Emissions from Worker Commuter Vehicles during Construction of a Neutralization/Biotreatment Facility at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Emission Rate (tons/yr)
HC	94,000	1.16	20	7.7
CO	94,000	11.38	20	75.5
NO <sub>x</sub>	94,000	0.73	20	4.8
SO <sub>x</sub>	94,000	0.12	20	0.8
PM <sub>10</sub>	94,000	0.055	20	0.4

<sup>a</sup> The number of auto round trips to the construction site was estimated on the basis of the average construction workforce and a 240 workdays per year.

<sup>b</sup> Emission factors determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on (DOE 1997).

added to the area. Table 5.43 presents the annual criteria pollutant emission estimates due to the increased traffic.

Additional emissions would result from the use of paints and thinners, aerosols, and other area source emissions. These emissions are expected to be minor contributors to air pollution, however, and were not included in current estimates.

Construction would generate solid wastes primarily in the form of excavation spoils and building material debris. These latter wastes would include concrete forms, equipment and hardware containers and packaging, paint cans, waste metal sheeting, pipe and wire, and landscaping debris. Small amounts of liquid wastes, such as solvents, cleaning solutions, and paint wastes also would be generated. Wastes would be collected and disposed of in accordance with U.S. Army, federal, state, and local requirements. All construction debris would be removed from the site for disposal. Any batteries, used motor oils, and empty containers would be separated from the waste stream and recycled. Any wastes that are identified as hazardous would be stored and disposed of in compliance with RCRA requirements. Sanitary wastes are the only significant liquid effluents that would be generated during construction.

Table 5.44 gives the estimated total quantities of solid and liquid wastes generated from activities associated with facility construction. The waste generation quantities are based on historic data on land area size and the construction labor force.

**TABLE 5.44 Estimated Total Wastes Generated during Construction of a Neutralization/Biotreatment Facility at BGAD**

Waste Category	Quantity
Hazardous solids	80 yd <sup>3</sup>
Hazardous liquids	31,000 gal
Nonhazardous solids	
Concrete <sup>a</sup>	210 yd <sup>3</sup>
Steel <sup>b</sup>	32 tons
Other <sup>c</sup>	1,700 yd <sup>3</sup>
Nonhazardous liquids	
Sanitary <sup>d</sup>	4.5E+06 gal
Other	2.0E+06 gal

<sup>a</sup> Amount of concrete (nonhazardous solid) waste was estimated by assuming 0.65% of concrete usage is spoilage.

<sup>b</sup> Amount of steel waste stream was estimated as 0.5% of steel requirement on the basis of LLNL et al. (1997).

<sup>c</sup> Amount of other stream was estimated as eight times the concrete stream based on LLNL et al. (1997).

<sup>d</sup> Amount of sanitary waste was estimated on the basis of the total construction workforce.

### 5.3.3.3 Operations Phase

Information on the facility operations phase is presented in this section. Preoperational testing is discussed first, followed by facility inputs and resource requirements, workforce requirements, and emissions and waste estimates.

#### 5.3.3.3.1 Preoperational Testing

A preoperational testing period assumed to last 12 months would begin following facility construction (Parsons/Allied Signal 1999). Often referred to as systemization, this period would be used to ensure that systems are operating as designed prior to full-scale operations. On the basis of similarity with baseline operations, it is projected that 315 FTEs would be needed at the peak of preoperational testing.

### 5.3.3.3.2 Operations Inputs and Resource Requirements

At full-scale operations, the stockpile of ACW containing mustard agent at BGAD is projected to require 16 days for processing (Mitretek 2001a). Assuming 276 operating days per year, operations would require approximately 0.6 calendar months (see Table 5.45). This duration is based on a 12-hours-per-day, 6-days-per-week operation, 46 weeks per year.<sup>61</sup>

Annual utility consumption for facility operation is presented in Table 5.46, including electricity, fuel, and potable water usage. The amount of process water that will be needed for steam generation and other processes has not been calculated because the technology provider purports that this process is a net producer of water. Table 5.47 shows annual usage of consumable chemicals and process material. These estimates are based on an assumed average or normal throughput.

Transportation data for annual (total) shipment of input material streams into BGAD are shown in Table 5.48. Hazardous materials shipped to the site include corrosives, such as NaOH and sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), oxidizer corrosives (hydrogen peroxide [H<sub>2</sub>O<sub>2</sub>]), and nonflammable gases (ammonia [NH<sub>3</sub>]).

### 5.3.3.3.3 Operations Workforce

The neutralization/biotreatment facility would be a government-owned, contractor-operated facility. The technology provider has stated that the expected operating and maintenance labor for neutralization/biotreatment should be similar to that for incineration (Parsons/Allied Signal 1999). Therefore, this analysis assumed that the estimated operations workforce needs are approximately 571 contractor employees for plant operations and

**TABLE 5.45 Inventory and Estimated Processing Time for Neutralization/Biotreatment of ACW Containing Mustard Agent at BGAD**

Munition	Quantity	Agent	Processing Rate (no. of munitions/h)	Processing Time		Changeover (weeks)	Total (weeks)
				Hours	Weeks <sup>a</sup>		
155-mm projectile	15,492	HD	80	194	2.7	0.0	2.7
Total	15,492			194	2.7	0.0	2.7

<sup>a</sup> Estimated by assuming 6 days-per-week and 12 hours-per-day operations.

<sup>61</sup> The full-scale scenario has been selected as the bounding case for this analysis.

**TABLE 5.46 Estimated Utilities Consumed during Destruction of ACW at the Neutralization/Biotreatment Facility at BGAD**

Utility	Average Daily Consumption	Peak Consumption	Annual Consumption
Process water	78,000 gal/d	1,900 gal/min	1,300,000 gal/yr
Potable water <sup>a</sup>	17,500 gal/d	180 gal/min	300,000 gal/yr <sup>b</sup>
Fire water <sup>a</sup>	NA <sup>c</sup>	3,000 gal/min	NA
Sanitary sewer <sup>a</sup>	20,650 gal/d	395 gal/min	300,000 gal/yr <sup>b</sup>
Natural gas	560,000 scf/d	44,000 scf/h	9,000,000 scf/yr <sup>d</sup>
Fuel oil <sup>d</sup>	962	406 gal/h	2,800 gal/yr <sup>e</sup>
Electricity	98 MWh	4.8 MW	1.6 GWh <sup>b,f</sup>

<sup>a</sup> Assumed to be similar to incineration because the number of operations and maintenance personnel and the land area are unchanged from incineration.

<sup>b</sup> Based on 16 campaign days.

<sup>c</sup> NA = not applicable.

<sup>d</sup> Estimate based on steam usage (16 days).

<sup>e</sup> Based on 35 hours of operations for a 16-day campaign.

<sup>f</sup> Based on an average power rating of 80%.

Source: PMCD (1998a).

**TABLE 5.47 Estimated Raw Materials Consumed Annually during Normal Neutralization/Biotreatment Operations at BGAD**

Material	Average Daily Consumption (lb/d)	Annual Consumption (tons/yr) <sup>a</sup>
Air for biotreater	3,200,000	25,600
Sodium hydroxide (NaOH)	11,000	90
Water (in caustic solution)	11,000	90
Sulfuric acid (H <sub>2</sub> SO <sub>4</sub> )	272	2.2
Dipotassium phosphate (K <sub>2</sub> HPO <sub>4</sub> )	522	4.2
Magnesium chloride (MgCl <sub>2</sub> )	196	1.6
Calcium chloride (CaCl <sub>2</sub> )	196	1.6
Ammonium phosphate ([NH <sub>4</sub> ] <sub>2</sub> HPO <sub>4</sub> )	980	7.9
Ammonia (NH <sub>3</sub> )	3,900	32
Ferrous sulfate (FeSO <sub>4</sub> )	65	0.5
Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )	1,600	13

<sup>a</sup> Estimated by assuming 38% availability of operations.

Source: Mitretek (2001a).

**TABLE 5.48 Transportation Data for Raw Materials for Neutralization/Biotreatment of ACW Containing Mustard Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	H <sub>2</sub> SO <sub>4</sub>	K <sub>2</sub> HPO <sub>4</sub>	MgCl <sub>2</sub>	CaCl <sub>2</sub>
Physical form	Liquid	Liquid	Solid, granular	Solid, granular	Solid, granular
Chemical composition/ temperature, pressure	NaOH/ ambient	H <sub>2</sub> SO <sub>4</sub> / ambient	K <sub>2</sub> HPO <sub>4</sub> / ambient	MgCl <sub>2</sub> / ambient	CaCl <sub>2</sub> / ambient
Packaging					
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50	50
Material weight (lb) <sup>a</sup>	700	840	1,080	1,060	990
Chemical content (wt%)	50% NaOH	93% H <sub>2</sub> SO <sub>4</sub>	100% K <sub>2</sub> HPO <sub>4</sub>	100% MgCl <sub>2</sub>	100% CaCl <sub>2</sub>
Shipments					
Average weight (tons/yr)	89.8	2.2	4.2	1.6	1.6
Average volume (ft <sup>3</sup> /yr)	1,909	38	58	22	24
Packages/yr	260	6	8	3	4
Packages/shipment	26	6	8	3	4
Shipments/yr	10	1	1	1	1
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Truck
Type of Data	Input Material No. 6	Input Material No. 7	Input Material No. 8	Input Material No. 9	
Transported materials					
Type/chemical	(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>	NH <sub>3</sub>	FeSO <sub>4</sub>	H <sub>2</sub> O <sub>2</sub>	
Physical form	Solid, granular	Liquid	Solid, granular	Liquid	
Chemical composition/ temperature, pressure	(NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub> / ambient	NH <sub>3</sub> /100°F, 197 psig (max)	FeSO <sub>4</sub> / ambient	H <sub>2</sub> O <sub>2</sub> / ambient	
Packaging					
Type	55-gal drum	Tank truck 5,500 gal	55-gal drum	55-gal poly drum	
Container volume (ft <sup>3</sup> )	7.35	735.24	7.35	7.35	
Certified by	DOT	DOT	DOT	DOT	
Identifier	Varies	MC-330, 331	Varies	Varies	
Container weight (lb)	50	NA <sup>b</sup>	50	50	
Material weight (lb) <sup>a</sup>	750	26,000	880	600	
Chemical content (wt%)	100% (NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub>	100% NH <sub>3</sub>	100% FeSO <sub>4</sub>	70% H <sub>2</sub> O <sub>2</sub>	



**TABLE 5.48 (Cont.)**

Type of Data	Input Material No. 6	Input Material No. 7	Input Material No. 8	Input Material No. 9
<b>Shipments</b>				
Average weight (tons/yr)	7.9	31.6	0.5	12.6
Average volume (ft <sup>3</sup> /yr)	156	1,824	9	314
Packages/yr	22	3	2	43
Packages/shipment	22	1	2	43
Shipments/yr	1	3	1	1
<b>Form of transport/routing</b>				
Form of transportation	Truck	Truck	Truck	Truck

<sup>a</sup> Based on Mitretek (2001a).

<sup>b</sup> NA = not applicable.

150 government employees for munition handling, security, oversight, and other support activities (PMCD 1997).

#### **5.3.3.3.4 Operations Emissions and Waste Estimates**

Wastes from the neutralization/biotreatment process would include air emissions and solid wastes. The only liquid effluent expected from the facility would be sanitary waste, which would be managed in an on-site treatment unit. All liquids generated by the agent neutralization/biotreatment process and all liquid laboratory wastes would be disposed of internally by neutralization/ biotreatment. Disposal facility operations, including waste management, would comply with U.S. Army, federal, state, and local requirements. Any wastes that are identified as hazardous would be stored and disposed of in compliance with RCRA requirements. The types of emissions and solid wastes are summarized below.

**Atmospheric Emissions.** Atmospheric emissions generated by facility operation would originate from the facility neutralization units, the ICB units, the process area carbon filtration/HEPA filter system, steam boilers, and vehicles; and from airborne dust from handling of solid residues and by vehicular traffic. Handling and disposal of biotreatment residue in accordance with the provisions of RCRA would result in little potential for significant adverse impacts on air quality. Emissions from vehicles and combustion of natural gas and LPG are regulated by the EPA and the State of Kentucky and also would result in little potential for significant adverse impacts on air quality. Dust emissions would be controlled during operations as well.

The process would be required to meet RCRA and any other applicable environmental requirements and would operate under permit. The neutralization/biotreatment system would be required to destroy agent to a DRE of 99.9999% and to meet agent emission limits as established by the ASG. Other emissions, including metals and HCl, would be regulated in accordance with the RCRA permit. The units also would be required to meet air pollution control requirements for conventional pollutants, such as CO, SO<sub>2</sub>, and opacity.

All ventilation air would be processed through carbon filtration units before being released to the atmosphere, except for that associated with the biotreatment units. Process off-gas from the various unit operations, including the biotreatment units, would be passed through catalytic converters (CatOx system) to oxidize compounds of concern. Facility effluent release points include gaseous releases to the environment. Table 5.49 summarizes the facility effluent air release points.

**TABLE 5.49 Stack Parameters for Neutralization/Biotreatment at BGAD<sup>a</sup>**

Installation or Emission Point	Physical Stack Height (ft)	Stack Exit Diameter (ft)	Stack Exit Gas Flow (acfm)	Stack Exit Gas Velocity (ft/s)	Stack Exit Gas Temp (°F)	Stack Location <sup>d</sup>
Process steam boiler I <sup>b</sup>	70	2	12,134	64.37	325	Near southwest corner of PUB
Process steam boiler II <sup>b</sup>	70	2	12,134	64.37	325	Near southwest corner of PUB
Process steam boiler III <sup>b</sup>	70	2	12,134	64.37	325	Near southwest corner of PUB
Diesel generator exhaust I	47	0.67	27,060	323	925	Near northwest corner of PMB
Diesel generator exhaust II	47	0.67	27,060	323	925	Near northwest corner of PMB
Biotreatment vent (waste gas) stack	80	1.5	5,150	48.57	143	Analogous to DUN Stack for incineration
Filter farm stack	120	6	96,000	56.58	77	Center of structure
Laboratory building stack	50	2.5	NA	NA	NA	Center of structure

<sup>a</sup> Abbreviations: NA = not available, PUB = Process Utilities Building, PMB = Personnel and Maintenance Building, DUN = dunnage.

<sup>b</sup> Stack exit gas flow modified to take into account the difference in process steam rate.

<sup>c</sup> No emissions during normal (incident-free) operations; the stack is operational only during upset conditions.

<sup>d</sup> Based on Drawings AB-D-41-0012 and AB-D-41-0013 in Volume II of APG (1997).

Source: APG (1997).

Table 5.50 summarizes the estimated criteria pollutant emission rates during operations; these rates were estimated on the basis of the annual (total) fuel consumption rates shown in Table 5.46. Daily emissions can be estimated from the hourly rates, assuming 12 operating hours per day.

Small amounts of organic and metallic compounds would be emitted from the combustion of natural gas during normal boiler operations and the combustion of fuel oil during emergency diesel generator operation. Tables 5.51 and 5.52 summarize the TAP emission rates during normal boiler operation and during emergency diesel operation, respectively.<sup>62</sup> These rates were estimated on the basis of the annual (total) consumption rates of fuels shown in Table 5.46 and using FIRE 6.22 emission factors for large wall-fired boilers with greater than 100 MMBtu/h of heat input and for reciprocating diesel operations (EPA 2000a). Daily emissions can be estimated from the hourly emissions, on the basis of the assumption that there are 12 operating hours per day.

The neutralization/biotreatment facility at BGAD would be equipped with building ventilation systems that would discharge indoor air from the MDB process area, the Laboratory Building, and the Personnel and Maintenance Building through the filter farm stack. Of the three ventilation systems, only the indoor air from the MDB process area would be potentially exposed to chemical agents during operations.

**TABLE 5.50 Estimated Hourly and Annual Criteria Pollutant Emission Rates during Normal Neutralization/Biotreatment Operations at BGAD**

Criteria Pollutant	Process Steam Boiler Stack <sup>a</sup>		Diesel Generator Exhaust Stack <sup>b</sup>	
	lb/h	tons/yr	lb/h	tons/yr
CO	3.9	0.38	10.4	0.18
NO <sub>x</sub>	6.5	0.63	48.4	0.85
SO <sub>2</sub>	0.03	0.00	3.2	0.06
PM <sub>10</sub>	0.35	0.03	3.4	0.06
HC	0.26	0.02	4.0	0.07

<sup>a</sup> Estimated from the daily requirement of process steam for a campaign of 16 days.

<sup>b</sup> Based on 35 hours of operations for a 16-day campaign.

Source: APG (1997).

<sup>62</sup> Many of the TAPs that would be emitted from the pilot test facility are HAPs, as defined in Section 112 of the CAA, Title III. The term TAP is broader in that it includes some pollutants that are not HAPs.

**TABLE 5.51 Estimated Hourly and Annual TAP Emission Rates during Normal Boiler Operations for Neutralization/Biotreatment at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)	Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
2-Methylnaphthalene	1.1E-06	2.2E-04	Dimethylbenz(a)anthracene	7.5E-07	1.4E-04
3-Methylchloranthrene	8.4E-08	1.6E-05	Ethane	1.4E-01	2.8E+01
Acenaphthene	8.4E-08	1.6E-05	Fluoranthene	1.4E-07	2.7E-05
Acenaphthylene	8.4E-08	1.6E-05	Fluorene	1.3E-07	2.5E-05
Anthracene	1.1E-07	2.2E-05	Formaldehyde	3.5E-03	6.8E-01
Arsenic	9.3E-06	1.8E-03	Hexane(n)	8.4E-02	1.6E+01
Barium	2.1E-04	4.0E-02	Indeno(1,2,3-cd)pyrene	8.4E-08	1.6E-05
Benz(a)anthracene	8.4E-08	1.6E-05	Lead	2.3E-05	4.5E-03
Benzene	9.8E-05	1.9E-02	Manganese	1.8E-05	3.4E-03
Benzo(a)pyrene	5.6E-08	1.1E-05	Mercury	1.2E-05	2.3E-03
Benzo(b)fluoranthene	8.4E-08	1.6E-05	Molybdenum	5.1E-05	9.9E-03
Benzo(g,h,i)perylene	5.6E-08	1.1E-05	Naphthalene	2.8E-05	5.5E-03
Benzo(k)fluoranthene	8.4E-08	1.6E-05	Nickel	9.8E-05	1.9E-02
Beryllium	5.6E-07	1.1E-04	Pentane(n)	1.2E-01	2.3E+01
Butane	9.8E-02	1.9E+01	Phenanthrene	7.9E-07	1.5E-04
Cadmium	5.1E-05	9.9E-03	Propane	7.5E-02	1.4E+01
Chromium	6.5E-05	1.3E-02	Pyrene	2.3E-07	4.5E-05
Chrysene	8.4E-08	1.6E-05	Selenium	1.1E-06	2.2E-04
Cobalt	3.9E-06	7.6E-04	Toluene	1.6E-04	3.1E-02
Copper	4.0E-05	7.7E-03	Vanadium	1.1E-04	2.1E-02
Dibenzo(a,h)anthracene	5.6E-08	1.1E-05			
Dichlorobenzene	5.6E-05	1.1E-02			

<sup>a</sup> Emission factors from EPA (2000a).

To estimate the maximum potential emissions of chemical agents, only the MDB process area was considered to be a significant potential source. The filter systems would be designed to remove chemical agents from the ventilation air streams to levels below the allowable stack concentrations recommended by the U.S. Department of Health and Human Services, Centers for Disease Control (53 *Federal Register* 8504 – 8507, March 15, 1988). Also, a negative pressure would be maintained at all times in the MDB after initiation of hot operations to inhibit the release of chemical agents. Estimated potential chemical agent emissions are presented in Table 5.53; the estimates were based on the assumption that the concentrations of chemical agents in the air discharged from the filter farm stack would be 20% of the recommended allowable stack concentrations (i.e., the level of quantification of the ventilation exhaust chemical agent monitors.) These emission calculations were based on operations time (12 hours per day, 276 days per year), since the only time there is a source of agent is during operations.

Tables 5.54 and 5.55 summarize the estimated TAP emission rates during operations from the biotreatment vent stack and the filter farm stack, respectively. Emission rates from the

**TABLE 5.52 Estimated Hourly and Annual TAP Emission Rates during Emergency Diesel Generator Operations for Neutralization/Biotreatment at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
Acenaphthene	3.1E-07	1.9E-04
Acenaphthylene	1.1E-06	6.7E-04
Acetaldehyde	1.7E-04	1.0E-01
Acrolein	2.0E-05	1.2E-02
Aldehydes	1.5E-02	9.2E+00
Anthracene	4.1E-07	2.5E-04
Benzene	2.0E-04	1.2E-01
Benzo(a)anthracene	3.7E-07	2.2E-04
Benzo(a)pyrene	4.1E-08	2.5E-05
Benzo(b)fluoranthene	2.2E-08	1.3E-05
Benzo(g,h,i)perylene	1.1E-07	6.4E-05
Benzo(k)fluoranthene	3.4E-08	2.0E-05
1,3-Butadiene	8.6E-06	5.1E-03
Chrysene	7.8E-08	4.6E-05
Dibenzo(a,h)anthracene	1.3E-07	7.7E-05
Fluoranthene	1.7E-06	1.0E-03
Fluorene	6.4E-06	3.8E-03
Formaldehyde	2.6E-04	1.6E-01
Indeno(1,2,3-cd)pyrene	8.2E-08	4.9E-05
Isomers of xylene	6.3E-05	3.7E-02
Mercury	6.6E-08	4.0E-05
Naphthalene	1.9E-05	1.1E-02
Phenanthrene	6.5E-06	3.9E-03
PAHs	3.7E-05	2.2E-02
Propylene	5.7E-04	3.4E-01
Pyrene	1.0E-06	6.3E-04
Toluene	9.0E-05	5.4E-02

<sup>a</sup> Emission factors from EPA (2000a).

biotreatment process are provided in Table 5.54, with and without off-gas treatment. The inclusion of off-gas treatment impacts the emission rates of organic compounds, such as 1,2-dichloroethane, and polychlorinated dioxins and furans, as shown in Table 5.54. Annual (total) emission rates can be estimated from the daily values, assuming 16 days of actual operations per year.

Emissions from operations worker commuter vehicles were estimated on the basis of the assumption that an average of 721 automobiles (1 car per operations worker) would be added to the area of the site and that each worker would drive an average of 20 mi (32 k) to the site. Table 5.56 presents the annual emission estimates due to the increased traffic.

**TABLE 5.53 Estimated Maximum Hourly and Annual Agent Emission Rates from the Filter Farm Stack during Neutralization/Biotreatment at BGAD**

Chemical Agent	Emission Factor (mg/m <sup>3</sup> ) <sup>a</sup>	Stack Exit Gas Flow (acfm) <sup>b</sup>	Hours of Operation per Year <sup>c</sup>	Stack Emission Rate	
				(lb/h)	(tons/yr) <sup>d</sup>
HD	0.006	96,000	194	2.2E-03	2.1E-04

<sup>a</sup> Based on the monitor level of quantification, which is 20% of the allowable stack concentration recommended for each chemical agent in 53 CFR 8504-8507.

<sup>b</sup> Filter farm stack exit flow based on building ventilation for the MDB.

<sup>c</sup> Based on 16 days of operations, 12 hours per day.

<sup>d</sup> Estimate based on annual number of hours of operation.

**Liquid Wastes.** As indicated previously, liquids from the biotreatment are evaporated, condensed, and reused. Other liquids, such as spent decontamination solutions and laboratory wastes, would be fed to the neutralization/biotreatment system. According to the technology provider, the only major liquid effluent expected to be generated at the facility is domestic sewage, which would be managed on-site. Small amounts of hazardous liquids could be generated from chemical makeup and reagents for support activities; it is anticipated that the quantities may be minor compared to those for domestic sewage (sanitary waste).

**Solid Wastes.** Solid wastes generated by the facility would consist primarily of biosolids and salts. Biosolids are the solid effluent from the bioreactor system; this effluent consists of microbial biomass and absorbed metals, grit, and dirt (see Table 5.57). Brine salts result from the hydrolysis process, facility washdown, and biotreatment. The salts would contain metals derived from ACW components and may be disposed of as hazardous waste in a RCRA-permitted facility (see Table 5.58). The sludge generated in the biotreatment system would be removed in the sludge treatment systems downstream of the ICB. The sludge would be separated from the water by means of a clarifier and would be dewatered and compacted by means of a filter press (see Table 5.59). Drummed filter cake may then be disposed of as hazardous waste in a RCRA-permitted facility.

Annual (total) waste generation rates can be estimated from the daily values, on the basis of the assumption that there would be 16 days of operations per year.

Nonhazardous scrap metal from the munition bodies (5X) would be sold to a scrap dealer or smelter for reuse, if approved by the regulatory authority (see Table 5.60). However, if it proves necessary, these metals could be disposed of off-site in a nonhazardous waste landfill or a permitted hazardous waste landfill. Currently, the U.S. Army does not intend to dispose of any waste materials from the disposal process on-site.

**TABLE 5.54 Estimated TAP Emission Rates from the Biotreatment Vent (Waste Gas) Stack during Neutralization/Biotreatment at BGAD<sup>a</sup>**

Compound	Emission Rate (lb/d)		Compound	Emission Rate (lb/d)	
	With HVAC Carbon/HEPA Filters	Without HVAC Carbon/HEPA Filters		With HVAC Carbon/HEPA Filters	Without HVAC Carbon/HEPA Filters
Organic compounds			Polychlorinated dioxins/furans		
1,2-Dichloroethane	9E-11	5E-03	1,2,3,4,6,7,8,9-OCDD	2E-13	3E-06
Acetaldehyde	2E-10	1E-02	1,2,3,4,6,7,8,9-OCDF	5E-14	5E-07
Bis(2-chloroethyl)ether	6E-11	4E-03	1,2,3,4,6,7,8-HpCDD	5E-14	5E-07
Bis(2-ethylhexyl)phthalate	9E-11	6E-03	1,2,3,4,6,7,8-HpCDF	5E-14	6E-07
Bromomethane	2E-10	2E-02	1,2,3,4,7,8,9-HpCDF	1E-14	2E-07
Chloromethane	2E-10	1E-02	1,2,3,4,7,8-HxCDD	2E-15	3E-08
Diethylphthalate	1E-10	6E-03	1,2,3,4,7,8-HxCDF	2E-14	2E-07
Ethyl benzene	7E-10	5E-02	1,2,3,6,7,8-HxCDD	5E-15	5E-08
Formaldehyde	2E-09	1E-01	1,2,3,6,7,8-HxCDF	7E-15	8E-08
Glycol ethers (2-butoxy ethanol)	6E-10	4E-02	1,2,3,7,8,9-HxCDD	9E-15	1E-07
m/p-Xylene	6E-09	4E-01	1,2,3,7,8-PeCDD	3E-16	3E-09
Mercury	3E-08	3E-03	1,2,3,7,8-PeCDF	7E-15	8E-08
Methyl ethyl ketone/butyraldehydes	8E-11	5E-03	2,3,4,6,7,8-HxCDF	7E-15	8E-08
Methylene chloride	2E-09	1E-01	2,3,4,7,8-PeCDF	1E-14	1E-07
Naphthalene	6E-11	4E-03	2,3,7,8-TCDD	4E-16	4E-09
Phenol	3E-11	2E-03	2,3,7,8-TCDF	1E-14	1E-07
Propanal	9E-11	6E-03	OCDD	4E-14	5E-07
Toluene	1E-10	8E-03	OCDF	2E-14	2E-07
			Total HpCDD	9E-14	1E-06
			Total HpCDF	9E-14	1E-06
			Total HxCDD	6E-14	7E-07
			Total HxCDF	6E-14	6E-07
			Total PeCDF	8E-14	9E-07
			Total TCDD	2E-15	2E-08
			Total TCDF	4E-14	4E-07

<sup>a</sup> Abbreviations: HEPA = high-efficiency particulate air filter; HVAC = heating, ventilation, and air-conditioning; HpCDD = heptachlorodibenzo-p-dioxin; HpCDF = heptachlorodibenzo-p-furan; HxCDD = hexachlorodibenzo-p-dioxin; HxCDF = hexachlorodibenzo-p-furan; OCDD = octachlorodibenzo-p-dioxin; OCDF = octachlorodibenzo-p-furan; PeCDD = pentachlorodibenzo-p-dioxin; PeCDF = pentachlorodibenzo-p-furan; TCDD = tetrachlorodibenzo-p-dioxin; and TCDF = tetrachlorodibenzo-p-furan.

Source: Mitretek (2001a).

Nonprocess waste streams include decon solution, DPE suits, spent carbon, waste oils, trash, debris, and spent hydraulic fluid, which are assumed to be potentially agent-contaminated, and that would be processed in the dunnage/waste processing system. After this processing, the only streams with a significant solid residue would be the decon solution (containing NaOH and NaOCl) and miscellaneous metal parts from equipment operation. Table 5.61 provides information on the daily and annual generation rates of treated, nonprocess wastes for ACW containing mustard agent.

The above waste streams may be shipped from the on-site facility to off-site locations. Table 5.62 provides transportation data for annual shipment of these waste streams and for

**TABLE 5.55 Estimated TAP Emission Rates from the Filter Farm Stack during Neutralization/Biotreatment at BGAD**

Compound	Emission Rate (lb/d)	Compound	Emission Rate (lb/d)
1,1,1-Trichloroethane	1E-14	Polychlorinated dioxins/furans	
1,2-Dichloroethane	2E-09	1,2,3,4,6,7,8,9-OCDD	3E-17
1,2-Dichloropropane	3E-14	1,2,3,4,6,7,8,9-OCDF	7E-17
1,4-Dichlorobenzene	3E-13	1,2,3,4,6,7,8-HpCDD	6E-17
3/4-Methylphenol	1E-13	1,2,3,4,6,7,8-HpCDF	6E-17
Benzene	9E-13	1,2,3,4,7,8,9-HpCDF	7E-18
Bis(2-ethylhexyl)phthalate	8E-13	1,2,3,4,7,8-HxCDD	7E-18
Bromomethane	3E-11	1,2,3,4,7,8-HxCDF	6E-17
Carbon disulfide	2E-11	1,2,3,6,7,8-HxCDD	2E-17
Carbon tetrachloride	3E-13	1,2,3,6,7,8-HxCDF	3E-17
Chlorobenzene	3E-11	1,2,3,7,8,9-HxCDD	2E-17
Chloroethane	4E-13	1,2,3,7,8,9-HxCDF	3E-18
Chloroform	6E-11	1,2,3,7,8-PeCDD	7E-18
Chloromethane	3E-10	1,2,3,7,8-PeCDF	1E-17
Chromium	2E-11	2,3,4,6,7,8-HxCDF	3E-17
Cobalt	2E-11	2,3,4,7,8-PeCDF	4E-17
Dimethylphthalate	2E-12	2,3,7,8-TCDF	1E-16
Ethyl benzene	8E-14	Dibenzofuran	3E-13
Lead	8E-13	Total HpCDD	1E-16
m,p-Xylene	4E-12	Total HpCDF	8E-17
Manganese	6E-12	Total HxCDD	2E-16
Mercury	2E-12	Total HxCDF	2E-16
Methyl ethyl ketone	1E-09	Total PeCDD	2E-16
Methylene chloride	3E-12	Total PeCDF	4E-16
Naphthalene	5E-12	Total TCDD	1E-16
Nickel	1E-11	Total TCDF	2E-12
o-Xylene	2E-13	Particulates	5E-08
Phenol	5E-13		
Phosphorus	2E-12		
Polycyclic organic matter (fluorene)	3E-12		
Selenium	2E-13		
Styrene	9E-17		
Tetrachloroethene	2E-14		
Toluene	4E-12		

Source: Mitretek (2001a).



**TABLE 5.56 Estimated Emissions from Worker Commuter Vehicles for Neutralization/Biotreatment Operations at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Emission Rate (ton/yr)
HC	11,600	1.16	20	1.0
CO	11,600	11.38	20	9.4
NO <sub>x</sub>	11,600	0.73	20	0.6
SO <sub>x</sub>	11,600	0.12	20	0.1
PM <sub>10</sub>	11,600	0.055	20	0.05

<sup>a</sup> Number of auto round trips to the operation site estimated on the basis of annual operating workforce and 16 campaign days.

<sup>b</sup> Emission factors determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub>, and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

nonprocess solids from neutralization/biotreatment. It was assumed that all wastes would be packaged in 55-gal (208-L) drums prior to off-site shipment.

The types and quantities of nonhazardous (nonprocess) solid and liquid wastes that could be generated from operation of the facility are shown in Table 5.63. The waste generation values are based on historical data on building size, utility requirements, and facility workforce.

#### 5.3.3.4 Activities

The PMACWA described activities for installation of the neutralization/biotreatment system (PMACWA 1999a). The major phases of the project are shown in Table 5.64.

#### 5.3.3.5 Uncertainties

Each of the individual technologies that form the neutralization/biotreatment system has either been previously proven as a successful technology or has been demonstrated by the PMACWA to be an acceptable technology for application at BGAD. However, demonstration testing focused on individual technologies and sometimes used less than full-scale units. In addition, although EDSs were conducted to evaluate the long-term adequacy of individual technologies, it was not possible to evaluate the long-term viability and performance of the

**TABLE 5.57 Estimated Generation Rates of Biomass from Neutralization/Biotreatment at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)	Compound	Generation Rate (lb/d)
Total biomass (including water)	13,000	Butyrolactone	2E-03
Biomass solids	8,300	Carbon disulfide	4E-02
1,2-Dichloroethane	3E-03	Carbonyl sulfide	2E-03
1,2-Dimethyl hydrazine	2E-02	Chloromethane	9E-02
1,3,5-Trithiane	4E-02	Copper	6E-02
1,3-Oxathiolane	5E-03	Diethylphthalate	1E-03
2-(2-Methoxyethoxy) ethanol	5E-03	Ethanol	2E-02
2,3-Butanedione	3E-02	Ethyl acetate	1E-02
2-Butanone	1	Ethyl benzene	1E-02
2-Methyl benzaldehyde	4E-02	Fluoranthene	8E-04
2-Methyl butaonic acid	5E-03	Lead	1E-02
2-Methyl-1,3-oxathilane	6E-03	Mercury	8E-05
2-Pentanone	2E-02	Methyl nitrate	5E-03
3-Hydroxy-2-butanone	8E-03	Nickel	8E-02
3-Methyl butaonic acid	2E-02	Nitrite	1
3-Penten-2-one	7E-03	Octadecanoic acid	9E-03
4-Hydroxy-4-methyl-2-pentanone	2E-03	Phenanthrene	2E-03
4-Methyl benzaldehyde	6E-03	Phenol	2E-03
4-Methylbenzene methanol	4E-03	Selenium	1E-02
4-Methylphenol	2E-02	Ocdd	8E-09
Acetaldehyde	7E-03	Silver	6E-03
Acetone	4E-01	Sulfide, reactive	8
Acetonitrile	4E-03	Tetrahydro-2-methyl thiophene	5E-03
Aluminum	5	Tin	2E-01
Barium	1E-02	Vanadium	8E-03
Benzeneacetic acid	8E-03	Xylenes	7E-02
Arsenic	1E-01	Zinc	4E-01
Bis(2-ethylhexyl)phthalate	4E-03	Water in biomass	4,500
Bromomethane	7E-03		

**TABLE 5.58 Estimated Generation Rates of Brine Salts from Neutralization/  
Biotreatment at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)	Compound	Generation Rate (lb/d)
Total brine salts (including water)	24,000	Bromomethane	2E-02
Sodium sulfate	4,700	Carbon disulfide	7E-02
Sodium bisulfate	8,100	Carbon tetrachloride	2E-02
Ferrous sulfate	70	Chlorobenzene	2E-02
Sodium chloride	6,800	Chloroethane	2E-02
Magnesium chloride	40	Chloroform	2E-02
Calcium chloride	40	Chloromethane	3E-02
Sodium nitrite	100	Chromium	1E-01
Ammonium phosphate	500	cis-1,3-Dichloropropene	2E-02
Dipotassium phosphate	300	Cobalt, total	6E-02
Sodium hydroxide	30	Copper	6E-02
1,1,1-Trichloroethane	2E-02	Copper, total	6E-02
1,1,2,2-Tetrachloroethane	2E-02	Cyclohexanone	1
1,1,2-Trichloroethane	2E-02	Dibromochloromethane	2E-02
1,1-Dichloroethane	2E-02	Ethylbenzene	2E-02
1,1-Dichloroethene	2E-02	Formaldehyde	20
1,2,5-Trithiepane	1E-01	Maltol	1E-02
1,2-Dichloroethane	2E-02	Manganese	3
1,2-Dichloroethene (total)	2E-02	Mercury	3E-03
1,2-Dichloropropane	2E-02	Methyl benzaldehyde	1E-02
1,3-Dithilane-2-thione	1E-02	Molybdenum	7E-02
1,3-Dithiolane	2E-01	m-Tolualdehyde	7E-02
1,4-Oxathiane-4,4-oxide	2E-01	Nickel	4E-01
1,4-Oxathiane-4-oxide	2E-01	Phenanthrene	6E-03
2,3-Butanedione	2E-02	Propanal	1
2-Butanone	1	Propanedioic acid	1E-02
2-Hexanone	2E-02	Selenium	1E-01
4-Methyl-2-pentanone	2E-02	Silver	5E-02
4-Methylphenol	4E-02	Styrene	2E-02
Acetaldehyde	0E+00	Sulfur dioxide	2E-02
Acetone	0E+00	Tetrachloroethene	2E-02
Aluminum	0E+00	Toluene	2E-02
Antimony	2E-01	Trans-1,3-dichloropropene	2E-02
Arsenic	1E-01	Trichloroethene	2E-02
Barium	3E-02	Vinyl chloride	2E-02
Benzene	2E-02	Xylenes	2E-01
Bromodichloromethane	2E-02	Zinc	8
Bromoform	2E-02	Water in salt cake	3,100

**TABLE 5.59 Estimated Generation Rates of Scrubber Sludge from Neutralization/Biotreatment at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)
Sodium sulfate (Na <sub>2</sub> SO <sub>4</sub> )	1.7E+03
Sodium chloride (NaCl)	6.8E+02
Water in salt cake	4.2E+02
Total	2.8E+03

**TABLE 5.60 Estimated Generation Rates of 5X Solids from Neutralization/Biotreatment at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)
Aluminum	5.8E+01
Steel and iron	7.8E+04
Copper	1.8E+03
Zinc	3.2E+02
Total	8.0E+04

entire, integrated treatment system. Thus, the primary uncertainty associated with neutralization/biotreatment is that the entire, integrated treatment system, with all its component units, has not been assembled and tested. The pilot program, if implemented for this technology system, would be designed to evaluate overall operability and long-term performance.

### 5.3.4 NEUTRALIZATION/GPCR/TW-SCWO

This description of the neutralization/GPCR/TW-SCWO technology system is based on several primary reports. A description of the proposed technology system can be found in the technology provider's demonstration report (Foster Wheeler/Eco Logic/Kvaerner 2000). As indicated in that report, many of the estimates provided for facility design and operation refer comparatively to the U.S. Army baseline incineration process, which indicates, in general, that

**TABLE 5.61 Calculated Quantities of Solid Residues from Nonprocess Wastes from Neutralization/Biotreatment of ACW Containing Mustard Agent at BGAD**

Waste Type	Inlet Waste Composition	Treatment Process	Product	Daily Quantity (lb/d)	Annual Quantity (tons/yr)
Decon solution	18 wt% NaOH, NaOCl <sup>a</sup>	MPT	50% NaOH, 50% NaOCl	860	6.9
Miscellaneous Metal parts	Nonmunition Scrap metal	MPT	100% Metal	380	3.1
Total				1,200	10

<sup>a</sup> Depending on the results of the test for hazardous constituents, off-site disposal at an RCRA-permitted facility may be required.

estimates are comparable to those associated with the baseline incineration process (General Atomics 1999). Thus, another of the primary sources of information for this section of the TRD is the EIS for disposal of chemical agents and munitions stored at Pine Bluff Arsenal, Arkansas (PMCD 1997). That is the most recent EIS that the U.S. Army has prepared for baseline incineration of chemical munitions.

In addition to the above, mass balance estimates, air emission estimates, and solid waste estimates for application of the neutralization/GPCR/TW-SCWO technology at BGAD have been developed (Mitretek 2001c). Air emissions and solid waste estimates for neutralization/GPCR/TW-SCWO, as discussed below, are based on Mitretek inputs, along with appropriate assumptions on filtration systems, plant operations, and schedule.

Many of the figures and tables referred to in the facility description for this technology system contain estimates (e.g., emissions, resources consumed) associated with processing ACW with a specified agent; these estimates are given on an annual basis (e.g., tons/yr). In some cases, the estimates have been converted from other units (e.g., lb/d) by accounting for the number of days of operation required for processing a specific type of ACW. This time period is referred to as a campaign; a campaign is agent-specific. The values in many of the following figures and tables are based on the number of days in the campaign required to process ACW containing mustard, GB, and VX agent. It was assumed that there are 276 operating days in a year. If the campaign is less than or equal to 276 days, annual quantities equal total quantities. If the campaign is greater than 276 days, quantities in the figures and tables are for 276 days of processing. In the latter case, the estimates provided are less than total quantities. Daily (or other) quantities may be obtained by adjusting for the number of days in the campaign.

**TABLE 5.62 Transportation Data for Solid Wastes from Neutralization/Biotreatment at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3	Output Material No. 4	Output Material No. 5
<b>Transported Materials</b>					
Type/chemical	Biomass – waste	Scrubber sludge – waste	Brine salts – waste	5X solids – waste	Nonprocess waste
Physical form	Solid	Solid	Solid	Solid	Solid
Chemical composition/ temperature, pressure	See Table 5.57	See Table 5.59	See Table 5.58	See Table 5.60	See Table 5.61
<b>Packaging</b>					
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum <sup>a</sup>	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50	50
Material weight (lb)	610	490	340	450	494
Chemical content (wt%)	See Table 5.57	See Table 5.59	See Table 5.58	See Table 5.60	See Table 5.61
<b>Shipments</b>					
Average weight (tons/yr) <sup>b</sup>	103	22	196	649	10
Average volume (ft <sup>3</sup> /yr)	2,520	680	8,700	21,600	300
Packages/yr	343	93	1,184	2,938	41
Packages/shipment	48	48	48	48	48
Shipments/yr	8	2	25	62	1
<b>Form of Transport/Routing</b>					
Form of transportation	Truck	Truck	Truck	Truck	Truck
Destination – facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Recycle	Land disposal <sup>a</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

<sup>b</sup> Estimated by assuming 16 campaign days per year.

<sup>c</sup> Depending on the test for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

**TABLE 5.63 Estimated Annual Nonhazardous (Nonprocess) Waste Generated during Neutralization/Biotreatment Operations at BGAD**

Category	Solid (yd <sup>3</sup> )	Liquid (gal)
Nonhazardous (sanitary) wastes	NA <sup>a</sup>	4.6E+06
Nonhazardous (other) wastes <sup>b</sup>	1,800	NA
Recyclable wastes <sup>c</sup>	720	NA

<sup>a</sup> NA = not applicable.

<sup>b</sup> Nonhazardous (other) wastes include domestic trash and office waste.

<sup>c</sup> Recyclable wastes include paper, aluminum, etc. generated by the facility.

**TABLE 5.64 Activities for Neutralization/Biotreatment at BGAD**

Key Milestones
EDS start
EDS testing start
Final EIS/ROD
Final design (65% completion)
RCRA Part B issued
MDB construction start
MDB construction finish
Systemization start (pilot train)
Systemization start (all trains)
Operations start
Operations finish

Source: PMACWA (1999a).

Figures 5.35 through 5.37 provide input/output material balances for the major streams for neutralization/GPCP/TW-SCWO of ACW containing mustard, GB, and VX agent, respectively. The amounts of air, potable water, natural gas input, treated off-gas, ventilation air, wastewater, and boiler flue gas shown in each of these figures represent total annual amounts.

#### **5.3.4.1 General Facility Description**

The proposed neutralization/GPCR/TW-SCWO facility is designed to fit approximately into the general configuration and site area as the baseline incineration process, except that it would require slightly more space (25%) for the MDB. Munitions access and disassembly, base hydrolysis, GPCR, and SCWO operations have been substituted for incineration operations. The physical plant would consist of a two-story building constructed of noncombustible materials, with a concrete structural frame and a low-slope concrete roof.

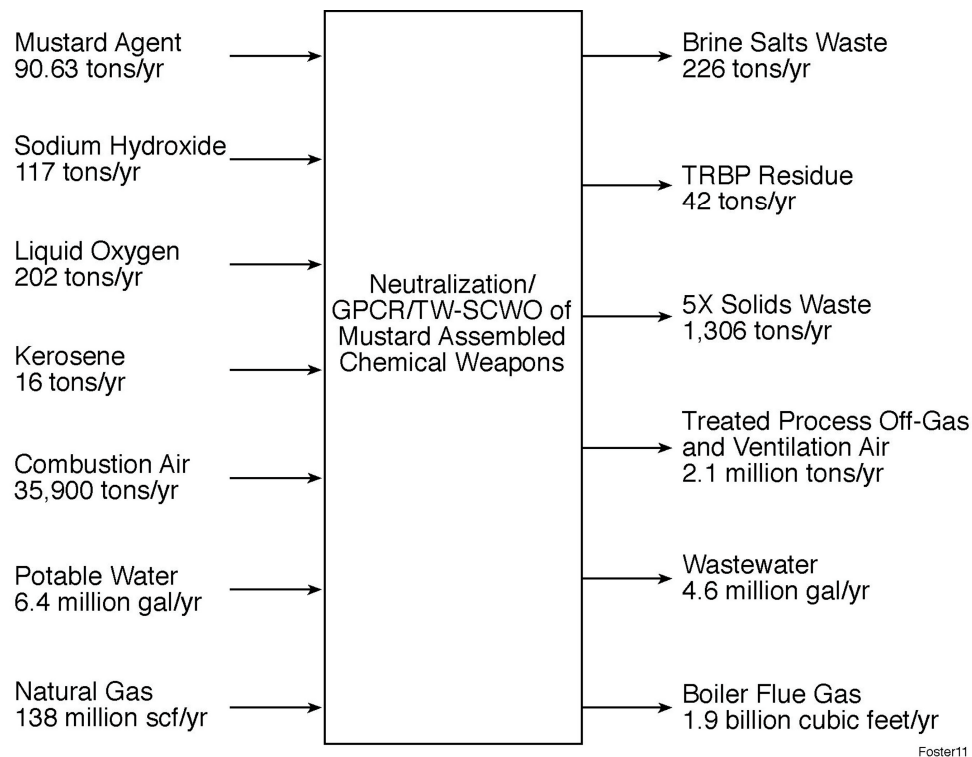
The site layout for the neutralization/GPCR/TW-SCWO facility is shown in Figures 5.38 through 5.40. Figure 5.38 shows the general facility layout, Figure 5.39 shows the arrangement of the first floor of the MDB, and Figure 5.40 shows the layout of the second floor of the MDB. Additional diagrams may be found in Foster Wheeler/Eco Logic/Kvaerner (2000). In addition, Foster Wheeler/Eco Logic/Kvaerner (2000) provides descriptions of the various units and operations that would be included in each section of the building, as shown in Figures 5.38 through 5.40.

#### **5.3.4.2 Construction Phase**

The schedule for destruction of the stockpile at BGAD, although tentative, calls for construction of the selected alternative to begin following issuance of the EIS ROD and receipt of the RCRA permit and any other environmental permits, as necessary. It is anticipated that the construction schedule for the neutralization/GPCP/TW-SCWO facility would be similar to that for the baseline incineration facility. Construction would take approximately 29 months (PMACWA 2001b), including include a two-month design and procurement verification period. However, the PMACWA is investigating means of shortening the construction phase.

Construction of the destruction facility on the BGAD installation would result in consumption of materials and resources, vehicle exhaust emissions, fugitive dust, noise, destruction of wildlife habitat and native vegetation, increased employment, increased demand for public services, and occupational health hazards.



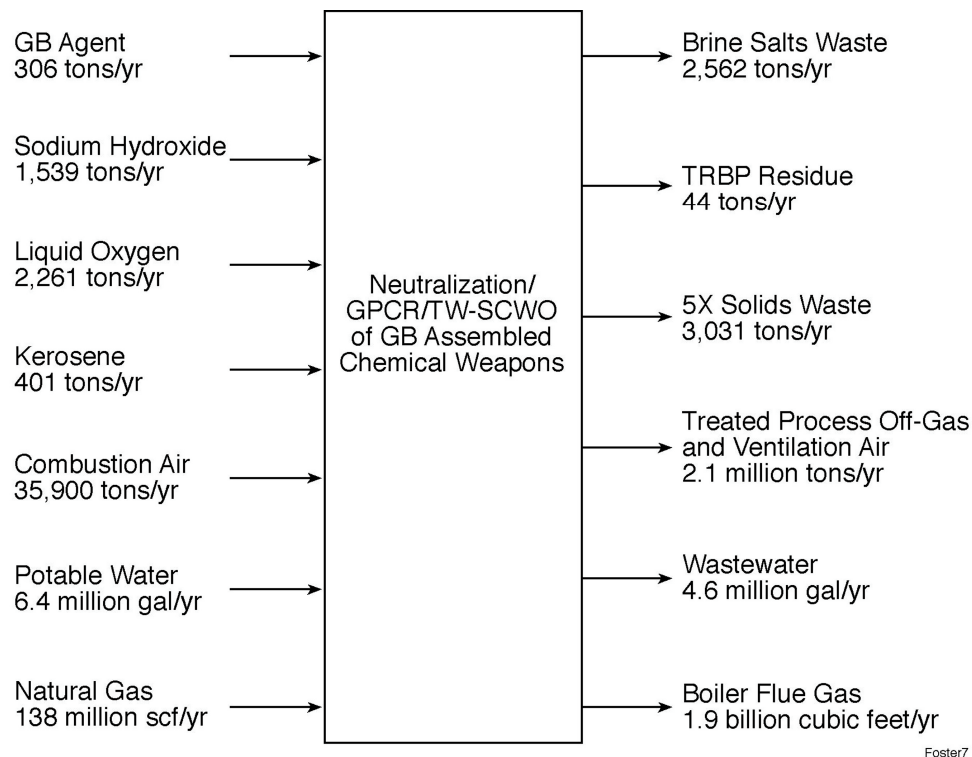


**FIGURE 5.34 Input/Output Material Balance for Neutralization/GPCR/TW-SCWO of ACW Containing Mustard Agent at BGAD**

#### 5.3.4.2.1 Construction Inputs and Resource Requirements

Resources and materials needed for constructing the destruction facility would include water, electricity, structural and piping steel, concrete, vehicle fuel, and industrial gases (propane). Table 5.65 contains order-of-magnitude estimates of the materials and resources that would be consumed during construction. These estimates are based on material and resource estimate methodologies used in engineering analyses and environmental documents concerning the DOE waste management activities. For example, the estimates of 20 gal (76 L) of water for each construction FTE and solidification requiring 26 lb (12 kg) of water for each 100 lb (45 kg) of cement are from the Waste Management Programmatic Environmental Impact Statement (DOE 1997). More precise estimates would require a detailed consideration of construction activities.

Process equipment would use some materials that also would be used in construction, such as steel. However, the amount of such material used for process equipment is expected to be small compared to that used in building construction, and, therefore, was not included in Table 5.65.



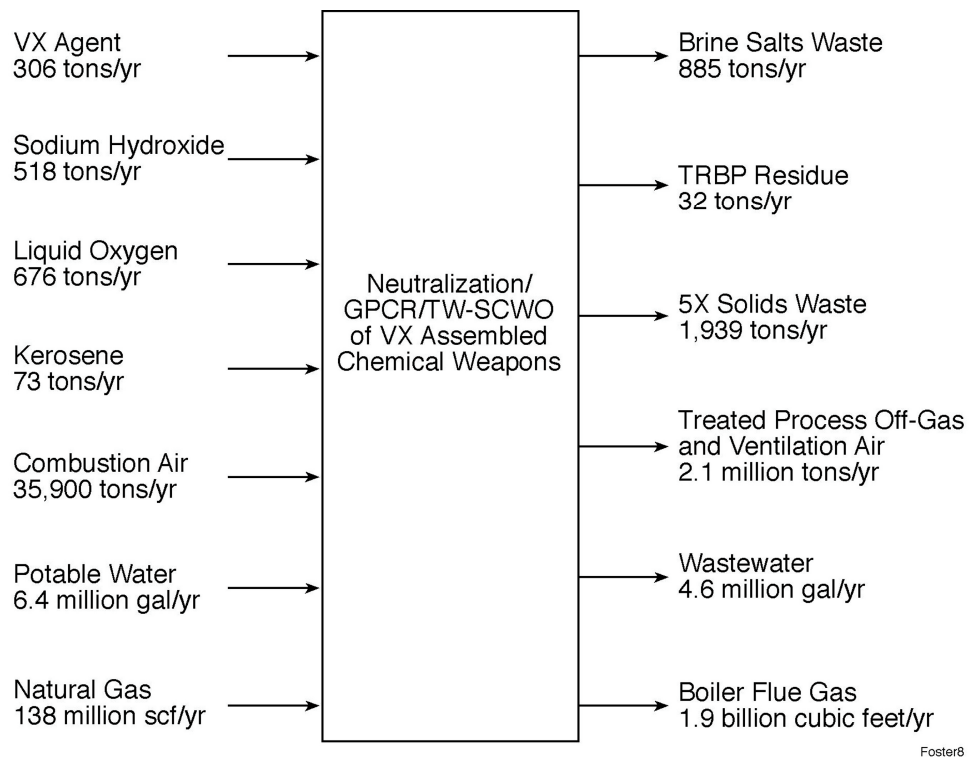
**FIGURE 5.35 Input/Output Material Balance for Neutralization/GPCR/TW-SCWO of ACW Containing GB Agent at BGAD**

Order-of-magnitude estimates of the number of shipments of construction material to the site are given in Table 5.66. These estimates do not include shipments of process and related equipment, the number of which is expected to be small compared to that for shipments of construction material. It was assumed that constituents of cement and backfill would be shipped in end-dump trucks with a capacity of 10 yd<sup>3</sup> (8 m<sup>3</sup>), that steel would be shipped on trucks with a 21-ton (19-t) net payload, and that liquid fuel would be shipped in tank trucks with a nominal capacity of 9,000 gal (34,000 L).

Table 5.67 provides order-of-magnitude estimates of the emissions of potential pollutants from construction delivery vehicles. It was assumed that the delivery vehicles would be heavy-duty diesel trucks and that the length of a one-way trip would be 20 mi (32 km) (roughly equal to the distance to the outskirts of Lexington, Kentucky). Actual trip distances would depend on a number of factors, including the availability of construction materials from local distributors and the distance of the site from the distributors.

#### 5.3.4.2.2 Construction Workforce

The construction workforce is expected to increase steadily to a peak of about 1,000 FTEs near the midpoint of the 29-month construction period, and then to decrease steadily

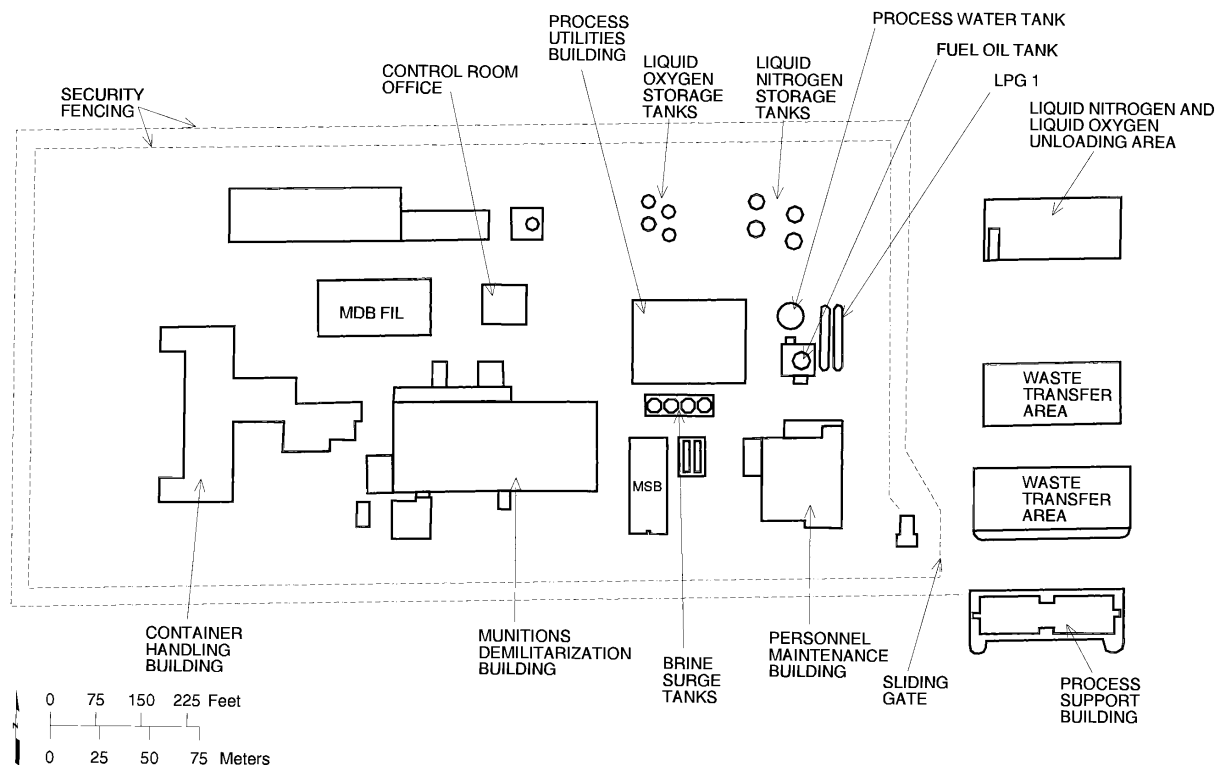


**FIGURE 5.36 Input/Output Material Balance for Neutralization/GPCR/TW-SCWO of ACW Containing VX Agent at BGAD**

until construction is completed. The average number of construction workers per month is estimated to be approximately 500 FTEs. The total effort during construction is estimated to be approximately 1,200 FTE-years. These estimates were developed from an activity-based approach that considered the various types of buildings, required instrumentation, process equipment installation, and other related construction activities. Table 5.68 provides an estimate of the employment buildup by year during construction.

#### 5.3.4.2.3 Construction Emissions and Waste Estimates

During the construction phase, fugitive emissions would consist mainly of dust and vehicle exhaust. Temporary, regional increases in atmospheric concentrations of CO, NO<sub>x</sub>, hydrocarbons, particulate matter, and SO<sub>x</sub> would result from the exhaust emissions of commuter vehicles, heavy construction vehicles, diesel generators, and other machinery and tools. Annual emissions of these pollutants would be small in comparison to de minimis levels used by regulators to determine whether an air quality permit or impact analysis is necessary. Emissions from construction vehicles are exempt from permit requirements. Nevertheless, vehicles and machinery would be equipped with standard pollution control devices to minimize air quality impacts.



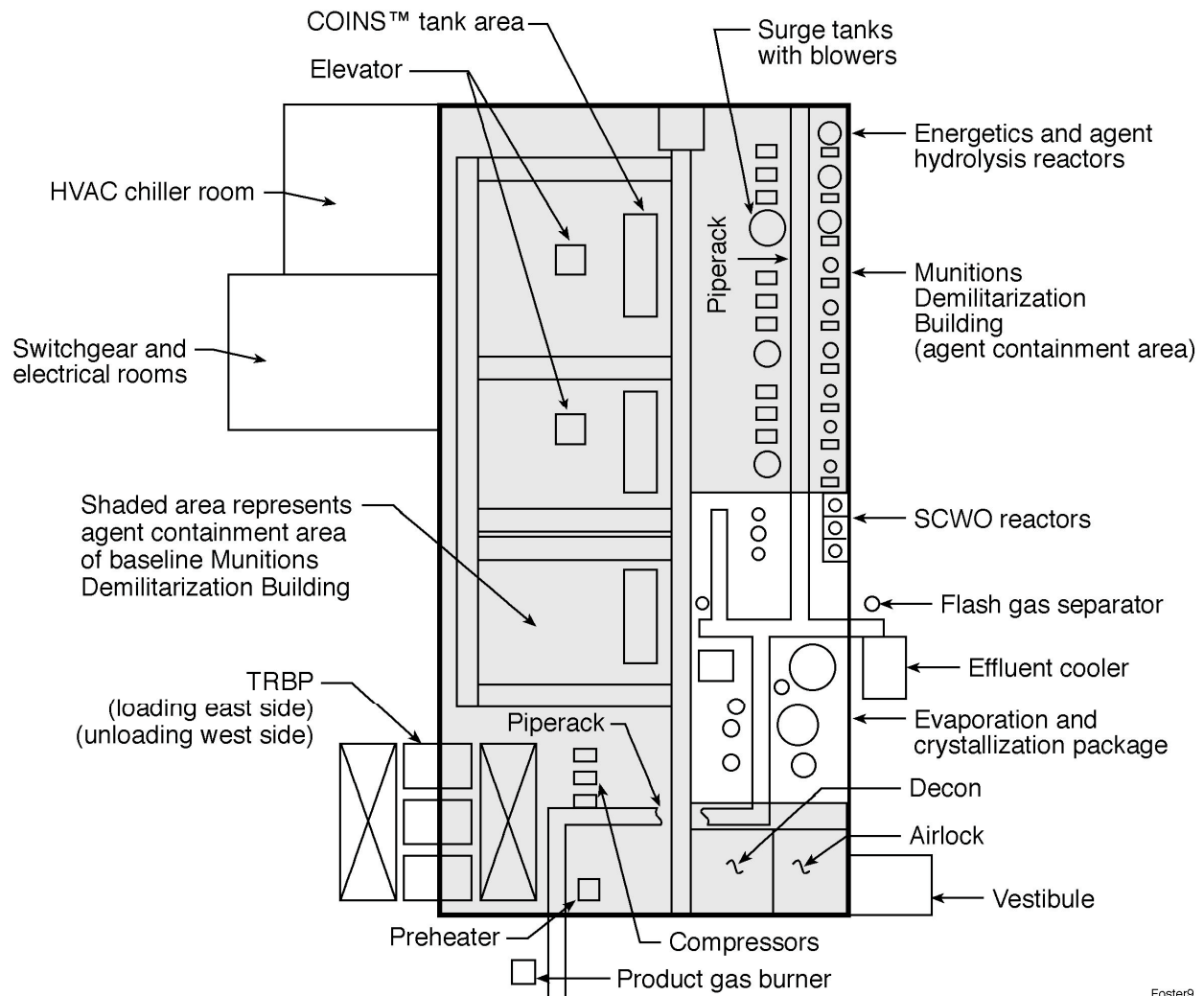
Foster12

**FIGURE 5.37 Neutralization/GPCR/TW-SCWO Facility Layout at BGAD (Source: Adapted from Foster Wheeler/Eco Logic/Kvaerner 2000)**

Estimated emissions from construction activities (not including emissions from delivery vehicles) are shown in Table 5.69. The emissions shown are based on the anticipated construction land disturbance and vehicle traffic (for dust particulate pollutants) and fuel and gas consumption. The column marked "Total" indicates the total amount of emissions that is estimated to occur over the entire construction period.

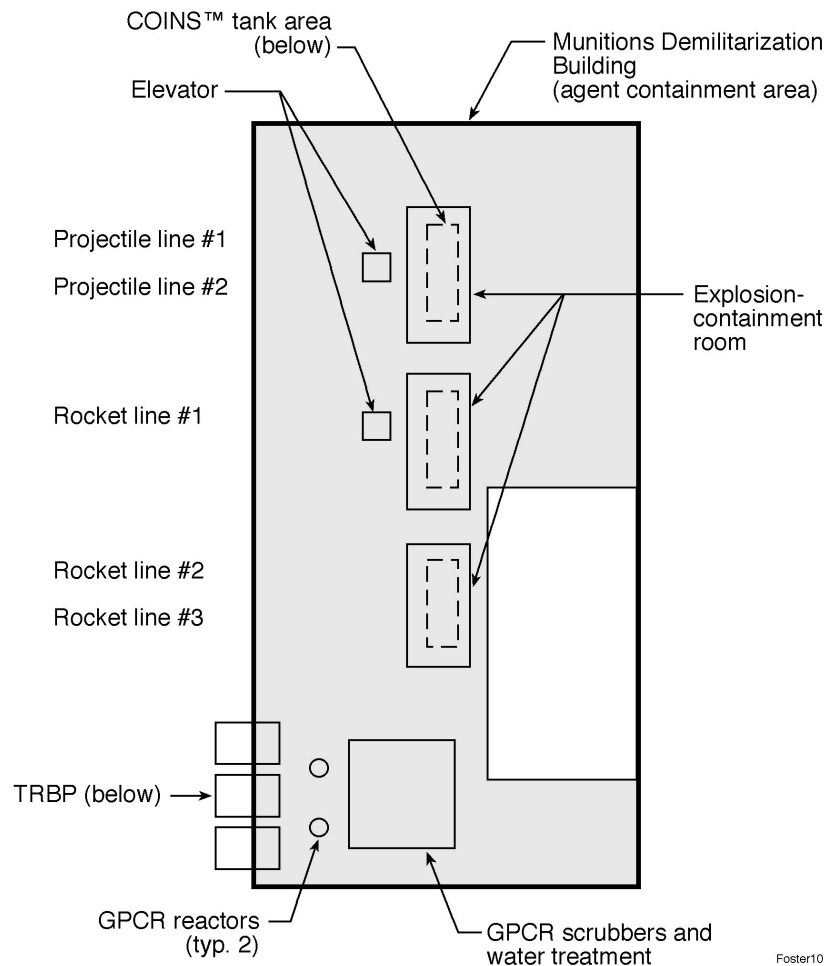
Emissions from construction worker commuter vehicles were estimated on the basis of the assumption that an average of about 500 automobiles (one car per construction worker) would be added to the area. As with construction delivery vehicles, it was assumed that a one-way trip in a commuter vehicle would be 20 mi (32 km). Table 5.70 gives the estimates of annual emissions of criteria pollutants arising from these trips.

Additional emissions would result from the use of paints and thinners, aerosols, and other area source emissions. These emissions are expected to be minor contributors to air pollution and were not included in current estimates.



**FIGURE 5.38 Layout of First Floor of the Munitions Demilitarization Building for the Neutralization/GPCR/TW-SCWO Facility at BGAD (Source: Adapted from Foster Wheeler/Eco Logic/Kvaerner 2000)**

Construction would generate solid waste primarily in the form of excavation spoils and building material debris. These latter wastes would include concrete forms, equipment and hardware containers and packaging, paint cans, waste metal sheeting, pipe and wire, and landscaping debris. Small amounts of liquid wastes, such as solvents, cleaning solutions, and paint wastes also would be generated. Wastes would be collected and disposed of in compliance with U.S. Army, federal, state, and local requirements. All construction debris would be removed from the site for disposal. Any batteries, used motor oils, and empty containers would be separated from the waste streams and recycled. Any wastes identified as hazardous would be stored and disposed of in accordance with RCRA requirements. Sanitary wastes are the only significant liquid effluent that would be generated during construction and would be managed on-site.



**FIGURE 5.39 Layout of Second Floor of the Munitions Demilitarization Building for the Neutralization/GPCR/TW-SCWO Facility at BGAD (Source: Adapted from Foster Wheeler/Eco Logic/Kvaerner 2000)**

The estimated total quantities of solid and liquid wastes generated from activities associated with facility construction are shown in Table 5.71. The waste generation quantities are based on historic data, land area size, and construction labor force.

### 5.3.4.3 Operations Phase

Information on the facility operations phase is presented in this section. Pre-operational testing is discussed first, followed by facility inputs and resource requirements, workforce requirements, and emissions and waste estimates.

**TABLE 5.65 Estimated Materials/Resources Consumed during Construction of a Neutralization/GPCR/TW-SCWO Facility at BGAD<sup>a</sup>**

Construction Material/Resource	Total Consumption	Peak Demand
Utilities		
Water <sup>b</sup>	9,000,000 gal	NA <sup>c</sup>
Electricity	62,000 MWh	3.1 MW
Solids		
Concrete	34,900 yd <sup>3</sup>	NA
Steel	5,800 tons	NA
Piping	96,000 linear ft	NA
Liquids		
Fuel	2.6E+06 gal	NA
Gases		
Industrial gases (propane) <sup>d</sup>	6,800 gal	NA

<sup>a</sup> All values can be considered order-of-magnitude approximations of the actual values; more accurate values would require a detailed consideration of construction activities.

<sup>b</sup> The water requirement was estimated on the basis of DOE (1997), in which each FTE required 20 gal/d, and solidification required 26 lb per 100 lb of cement.

<sup>c</sup> NA = not applicable.

<sup>d</sup> Scaling method based on Folga et al. (1999).

#### 5.3.4.3.1 Preoperational Testing

A preoperational testing period assumed to last 14 months would begin following facility construction (PMACWA 2001b). Often referred to as systemization, this period would include preoperational checkout, training, and integrated systems operation under mock conditions with simulated munitions filled with surrogate chemicals (PMCD 1997). Systemization would be used to ensure that systems are operating as designed prior to pilot-scale operations. Therefore, it would appear that no hazardous emissions or effluents would be generated. The only types of effluents that would be generated would be criteria pollutants (during testing of the steam boilers and the emergency diesel generator) and sanitary waste (from the systemization workforce). The amounts of criteria pollutants released and sanitary wastes generated would be negligible compared with those during construction and operations; thus, they were not considered in this analysis. It is projected that 315 contractor FTE-years would be needed for systemization.

**TABLE 5.66 Order-of-Magnitude Estimate of the Number of Truck Shipments of Construction Materials for Construction of a Neutralization/GPCR/TW-SCWO Facility at BGAD<sup>a</sup>**

Resource	Total Consumption	Truck Capacity	No. Truck Shipments
Portland cement <sup>b</sup>	3,839 yd <sup>3</sup>	10 yd <sup>3</sup>	384
Gravel <sup>b</sup>	14,309 yd <sup>3</sup>	10 yd <sup>3</sup>	1,431
Sand <sup>b</sup>	9,074 yd <sup>3</sup>	10 yd <sup>3</sup>	908
Steel <sup>c</sup>	5,800 tons	21 tons	280
Asphalt paving <sup>d</sup>	1,200 tons	20 tons	60
Backfill <sup>e</sup>	11,400 yd <sup>3</sup>	10 yd <sup>3</sup>	1,140
Fuel <sup>f</sup>	2.6E+06 gal	9,000 gal	290
Total			4,493
Total (rounded up)			5,000

<sup>a</sup> The calculation did not include truck deliveries of process equipment and related items.

<sup>b</sup> Assumes that concrete is composed of 11% portland cement, 41% gravel, and 26% sand, and is shipped to the site in a standard 10-yd<sup>3</sup> end-dump truck.

<sup>c</sup> Assumes that the net payload for steel transport to the site is 42,000 lb.

<sup>d</sup> Assumes HMA is loaded into 20-ton capacity triaxle trucks for transport to the paving site.

<sup>e</sup> Assumes shipment is in standard 10-yd<sup>3</sup> end-dump trucks and no fill is available on-site.

<sup>f</sup> Assumes shipment is in a DOT 406/MC-306 atmospheric pressure tank truck with a 9,000-gal capacity.

#### 5.3.4.3.2 Operations Inputs and Resource Requirements

At full-scale operation, destruction of the mustard agent inventory at BGAD is projected to require 16 days for processing, and destruction of the nerve agent inventory is projected to require 319 days (232 for GB and 87 for VX). Destruction operations at BGAD are projected to require approximately 15.5 months at full-scale operation (see Table 5.72). This duration is based on a 12-hours-per-day, 6-days-per-week operation, 4 weeks per month, with two 3-week munition changeover periods.

Estimated annual utility consumption for facility operation, including electricity, fuel, and potable water usage, is presented in Table 5.73. The estimates in Table 5.73 are based on the assumption that the facility would consume potable water and produce sanitary waste 365 days per year. These are conservative assumptions that would identify an upper bound to potable



**TABLE 5.67 Estimated Emissions from Delivery Vehicles during Construction of a Neutralization/GPCR/TW-SCWO Facility at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Construction Period (yr)	Emission Rate (tons/yr)
HC	5,000	2.12	20	2.4	0.3
CO	5,000	11.28	20	2.4	1.7
NO <sub>x</sub>	5,000	1.25	20	2.4	0.2
SO <sub>x</sub>	5,000	0.23	20	2.4	0.03
PM <sub>10</sub>	5,000	0.617	20	2.4	0.1

<sup>a</sup> Number of auto round trips to the construction site estimated on the basis of the total number of deliveries.

<sup>b</sup> Emission factors determined using EPA computer modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

**TABLE 5.68 Estimated Number of Employees Needed by Year for Construction of a Neutralization/GPCR/TW-SCWO Facility at BGAD**

Employees	Year 1	Year 2	Year 3
Total craft workers	340	560	60
Construction management and support staff	80	140	20
Total	420	700	80

**TABLE 5.69 Estimated Emissions during Construction of a Neutralization/GPCR/TW-SCWO Facility at BGAD**

Criteria Pollutant	Total (tons)	Annual (tons/yr)
CO	129	53
HC	54	22
NO <sub>x</sub>	192	79
SO <sub>x</sub>	13	5
Particulates	379	157

**TABLE 5.70 Estimated Emissions from Worker Commuter Vehicles during Construction of a Neutralization/GPCR/TW-SCWO Facility at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Emission Rate (tons/yr)
HC	119,000	1.16	20	9.8
CO	119,000	11.38	20	96.1
NO <sub>x</sub>	119,000	0.73	20	6.2
SO <sub>x</sub>	119,000	0.12	20	1.0
PM <sub>10</sub>	119,000	0.055	20	0.5

<sup>a</sup> Number of auto round trips to the construction site estimated on the basis of the total construction workforce and an assumption of 240 workdays per year.

<sup>b</sup> Emission factors determined by using EPA modeling software Mobile5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

water and sanitary waste treatment requirements. It was also assumed conservatively that fuel oil would be consumed only by an emergency diesel generator that would operate 600 hours per year. This analysis assumed that the amount of natural gas consumed for space heating would be negligible compared with the amount of natural gas consumed during the destruction process.

Destruction processes would consume raw materials. Table 5.74 gives the amounts of LOX, NaOH, and kerosene that would be consumed during the processing of the three agents.

Tables 5.75 through 5.77 present transportation data estimated using the input material streams from Mitretek (2001c) for liquid oxygen (LOX), NaOH, and kerosene for mustard, GB, and VX agent processing, respectively. Each of these materials would be transported to the site as a liquid by truck. The NaOH would be transported in 55-gal (208-L) drums. The other two materials would be transported in bulk by tanker truck.

#### 5.3.4.3.3 Operations Workforce

The neutralization/GPCR/TW-SCWO facility would be a government-owned, contractor-operated facility. Contractor employees would handle plant operations, while government employees would handle munitions, provide security, and staff other support activities. It is estimated that 721 FTEs (571 FTEs of contractor employee effort and 150 FTEs of government employee effort) would be needed (PMCD 1997).

**TABLE 5.71 Estimated Total Wastes Generated during Construction of a Neutralization/GPCR/TW-SCWO Facility at BGAD**

Waste Category	Quantity
Hazardous solids	100 yd <sup>3</sup>
Hazardous liquids	34,000 gal
Nonhazardous solids	
Concrete <sup>a</sup>	230 yd <sup>3</sup>
Steel <sup>b</sup>	29 tons
Other <sup>c</sup>	1,800 yd <sup>3</sup>
Nonhazardous liquids	
Sanitary <sup>d</sup>	4,800,000 gal
Other	2,200,000 gal

<sup>a</sup> Amount of concrete (nonhazardous solid) waste was estimated by assuming that 0.65% of concrete usage is spoilage.

<sup>b</sup> Amount of steel waste stream was estimated as 0.5% of steel requirement based on LLNL et al. (1997).

<sup>c</sup> Amount of other stream estimated as eight times the concrete stream based on LLNL et al. (1997).

<sup>d</sup> Amount of sanitary waste was estimated on the basis of the total construction workforce.

**TABLE 5.72 Inventory and Estimated Processing Time for Neutralization/GPCR/TW-SCWO of the ACW Stored at BGAD**

Munition	Quantity	Agent	Processing Rate (no. of munitions/h)	Processing Time		Changeover (weeks)	Total (weeks)
				Hours	Weeks <sup>a</sup>		
155-mm projectile	15,492	HD	80	194	2.7	0.0	2.7
8-in. projectile	3,977	GB	20	199	2.8	3.0	5.8
M55 rocket	51,716	GB	20	2,586	35.9	0.0	35.9
155-mm projectile	12,816	VX	80	160	2.2	3.0	5.2
M55 rocket	17,733	VX	20	887	12.3	0.0	12.3
Total	101,734			4,025	55.9	6.0	61.9

<sup>a</sup> Estimated by assuming 6-days-per-week operations and 12 hours per day.

**TABLE 5.73 Estimated Utilities Consumed during Destruction of ACW at the Neutralization/GPCR/TW-SCWO Facility at BGAD**

Utility	Average Daily Consumption	Peak Consumption	Annual Consumption
Process water <sup>a</sup>	64,000 gal/d	3,600 gal/h	18,000,000 gal/yr
Potable water <sup>b</sup>	17,500 gal/d	180 gal/min	6,400,000 gal/yr <sup>c</sup>
Fire water <sup>b</sup>	NA <sup>d</sup>	3,000 gal/min	NA
Sanitary sewer <sup>b</sup>	20,650 gal/d	395 gal/min	7,500,000 gal/yr <sup>c</sup>
Natural gas <sup>a</sup>	500,000 scf/d	579,000 scf/d	138,000,000 scf/yr <sup>c</sup>
Fuel oil	962 gal/d	406 gal/h	48,000 gal/yr <sup>f</sup>
Electricity	72 MWh	3.5 MW	26.3 GWh <sup>c,g</sup>

<sup>a</sup> Estimated on the basis of the munitions processing rate and unit utility factors for neutralization/GPCR/TW-SCWO technology.

<sup>b</sup> Assumed to be similar to incineration because the number of operations and maintenance personnel and land area are unchanged from incineration.

<sup>c</sup> Based on 365 days of operations per year.

<sup>d</sup> NA = not applicable.

<sup>e</sup> Based on 276 days of operations per year.

<sup>f</sup> Based on 600 hours of emergency diesel generator operation per year.

<sup>g</sup> Based on an average power rating of 80%.

Source: Carnes (2001).

**TABLE 5.74 Estimated Raw Materials Consumed Annually during Normal Neutralization/GPCR/TW-SCWO Operations at BGAD**

Agent Processed	Material	Material Consumed	
		Average Daily Consumption (lb/d)	Annual Consumption (tons/yr) <sup>a</sup>
Mustard agent, nominal 16-day campaign	LOX	25,010	202
	NaOH	14,435	117
	Kerosene for SCWO	1,947	16
GB, nominal 232-day campaign	LOX	19,487	2,261
	NaOH	13,266	1,539
	Kerosene for SCWO	3,453	401
VX, nominal 87-day campaign	LOX	15,505	676
	NaOH	11,866	518
	Kerosene for SCWO	1,666	73

<sup>a</sup> Annual estimates based on a nominal campaign length for the respective agent.

Source: Mitretek (2001c).

**TABLE 5.75 Transportation Data for Raw Materials for Neutralization/ GPCR/TW-SCWO of ACW Containing Mustard Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3
Transported materials			
Type/chemical	NaOH	LOX	Kerosene
Physical form	Liquid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	O <sub>2</sub> /-297°F, 1 atm	Kerosene/ ambient
Packaging			
Type	55-gal drum	4,000-gal tanker truck	5,500-gal tank truck
Container volume (ft <sup>3</sup> )	7.35	535	735
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	NA <sup>a</sup>	NA
Material weight (lb) <sup>b</sup>	700	38,080	39,020
Chemical content (wt%)	50% NaOH	100% O <sub>2</sub>	N/A
Shipments			
Average weight (tons/yr) <sup>c</sup>	117	202	16
Average volume (ft <sup>3</sup> /yr)	2,478	5,668	592
Packages/yr	338	11	1
Packages/shipment	48	1	1
Shipments/yr	8	11	1
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Specific gravity (77°F)	NA	1.107	0.85

<sup>a</sup> NA = not applicable.<sup>b</sup> Based on Mitretek (2001c).<sup>c</sup> Estimated on the basis of a total campaign length of 16 operating days.

**TABLE 5.76 Transportation Data for Raw Materials for Neutralization/ GPCR/TW-SCWO of ACW Containing GB Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3
Transported materials			
Type/chemical	NaOH	LOX	Kerosene
Physical form	Liquid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	O <sub>2</sub> /-297°F, 1 atm	Kerosene/ ambient
Packaging			
Type	55-gal drum	4,000-gal tanker truck	5,500-gal tank truck
Container volume (ft <sup>3</sup> )	7.35	535	735
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	NA <sup>a</sup>	NA
Material weight (lb) <sup>b</sup>	700	38,080	39,020
Chemical content (wt%)	50% NaOH	100% O <sub>2</sub>	N/A
Shipments			
Average weight (tons)/yr <sup>c</sup>	1,539	2,261	401
Average volume (ft <sup>3</sup> /yr)	32,708	63,500	15,098
Packages/yr	4,449	119	21
Packages/shipment	48	1	1
Shipments/yr	93	119	21
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Specific gravity (77°F)	NA	1.1407	0.85

<sup>a</sup> NA = not applicable.

<sup>b</sup> Based on Mitretek (2001c).

<sup>c</sup> Estimated on the basis of a total campaign length of 232 operating days.

**TABLE 5.77 Transportation Data for Raw Materials for Neutralization/GPCR/TW-SCWO of ACW Containing VX Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3
Transported materials			
Type/chemical	NaOH	LOX	Kerosene
Physical form	Liquid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	O <sub>2</sub> /-297°F, 1 atm	Kerosene/ ambient
Packaging			
Type	55-gal drum	4,000-gal tanker truck	5,500-gal tank truck
Container volume (ft <sup>3</sup> )	7.35	535	735
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	NA <sup>a</sup>	NA
Material weight (lb) <sup>b</sup>	700	38,080	39,020
Chemical content (wt%)	50% NaOH	100% O <sub>2</sub>	NA
Shipments			
Average weight (tons/yr) <sup>c</sup>	518	676	73
Average volume (ft <sup>3</sup> /yr)	10,999	18,994	2,739
Packages/yr	1,496	36	4
Packages/shipment	48	1	1
Shipments/yr	32	36	4
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Specific gravity (77°F)	NA	1.1407	0.85

<sup>a</sup> NA = not applicable.

<sup>b</sup> Based on Mitretek (2001c).

<sup>c</sup> Estimated on the basis of a total campaign length of 87 operating days.

#### 5.3.4.3.4 Operations Emissions and Waste Estimates

Wastes from the neutralization/GPCR/TW-SCWO process would include air emissions and solid wastes. The only liquid effluent from the facility would be sanitary waste, which would be managed in an on-site treatment unit. All liquids generated by the process and all liquid laboratory wastes would be reused in the process or destroyed internally by the neutralization/GPCR/TW-SCWO process. Destruction facility operations, including waste management, would comply with U.S. Army, federal, state, and local requirements. Any wastes that are identified as hazardous (e.g., SCWO salts and GPCR residues) would be stored and disposed of in compliance with RCRA requirements.

The only solid effluents from the process would include salts from TW-SCWO and solid residues from GPCR. Solid residues from GPCR collected during the PMACWA Demo II Test Program passed the TCLP requirements, with the exception of DPE runs (Foster Wheeler/Eco Logic/Kvaerner 2000).

**Gas Effluents.** GPCR gas (including COINS and hydrolysate reactors gas streams) containing hydrogen, CH<sub>4</sub>, CO<sub>2</sub> and acid gases would be scrubbed with caustic and then held for agent testing. Once cleared, the gas would be passed through a boiler or energy recovery device and then a catalytic converter. The gas product from GPCR would be a RCRA hazardous waste, but may be burned in a BIF if it meets certain requirements. The final technical evaluation for this technology (PMACWA 2001b) states that it appears likely that the GPCR product would exceed the specific heating value threshold (5,000 Btu/h) that is used as a key test to determine the applicability of the BIF exemption.

Product gases would be scrubbed before release to the plant ventilation system. These product gases would be stored and tested prior to release to the atmosphere. Thus, if their concentrations leaving the scrubbers are not acceptable, they would reenter the GPCR process. Consequently, it was assumed that emissions from the product gas burner vent would not be further treated after release from the scrubbers. Facility effluent release points would include gaseous releases to the environment. Table 5.78 summarizes the facility air release points.

Handling and disposal of process residue in accordance with the provisions of RCRA are expected to result in little potential for significant adverse impacts on air quality. Emissions from vehicles and combustion of natural gas and LPG are regulated by the EPA and the State of Kentucky and are expected to result in little potential for significant adverse impacts on air quality. Dust emissions would be controlled during operations as well.

The neutralization/GPCR/TW-SCWO process would be required to meet RCRA and any other applicable environmental requirements, as necessary, and would operate under permit. Permit conditions are expected to require the process to destroy agent and energetics to a DRE of 99.9999% and to meet agent emission limits as established by the ASG. Other emissions,



**TABLE 5.78 Stack Parameters for Neutralization/GPCR/TW-SCWO at BGAD<sup>a</sup>**

Installation or Emission Point	Physical Stack Height (ft)	Stack Exit Diameter (ft)	Stack Exit Gas Flow (acfm)	Stack Exit Gas Velocity (ft/s)	Stack Exit Gas Temp (°F)	Stack Location <sup>b</sup>
Process steam boiler I <sup>b,c</sup>	70	1.1	3,198	60	325	Near southwest corner of PUB
Process steam boiler II <sup>b,c</sup>	70	1.1	3,198	60	325	Near southwest corner of PUB
Process steam boiler III <sup>b,c</sup>	70	1.1	3,198	60	325	Near southwest corner of PUB
Diesel generator exhaust I <sup>b</sup>	47	0.67	6,765	323	925	Near northwest corner of PMB
Diesel generator exhaust II <sup>b</sup>	47	0.67	6,765	323	925	Near northwest corner of PMB
Filter farm stack <sup>d,e</sup>	120	6.8	131,000	60	77	Center of structure
Product gas burner stack <sup>d,e</sup>	80	0.417	510	62.34	77	Southwest corner of the MDB

<sup>a</sup> Abbreviations: MDB = Munitions Demilitarization Building, PMB = Personnel and Maintenance Building, and PUB = Process Utilities Building.

<sup>b</sup> Information on the stack characteristics for neutralization/SCWO was unavailable; characteristics similar to neutralization/biotreatment were assumed (Parsons/Allied Signal 1999).

<sup>c</sup> Stack exit gas flow for the process steam boiler taken from Parsons/Allied Signal (1999) and modified to take into account the annual average natural gas consumption rate of 500,000 scf/d for neutralization/GPCR/TW-SCWO.

<sup>d</sup> Stack characteristics similar to those at Newport, Indiana assumed (PMCD 1999).

<sup>e</sup> Stack exit gas flow and diameter revised to account for a 25% increase in the MDB proposed by the technology provider (Foster Wheeler/Eco Logic/Kvaerner 2000).

including metals and HCl, would be regulated in accordance with the RCRA permit. The operation would also be required to meet air pollution control requirements for conventional pollutants, such as CO, SO<sub>2</sub>, and opacity.

Table 5.79 summarizes the estimated criteria pollutant emission rates during operations; these rates were estimated on the basis of the annual fuel consumption rates shown in Table 5.73. Daily emissions can be estimated from the hourly rates, assuming 12 hours of operation per day.

Small amounts of organic and metallic compounds would be emitted from the combustion of natural gas during normal boiler operation and from the combustion of fuel oil

**TABLE 5.79 Estimated Hourly and Annual Criteria Pollutant Emission Rates during Normal Neutralization/GPCR/TW-SCWO Operations at BGAD**

Criteria Pollutant	Process Steam Boiler Stack <sup>a</sup>		Diesel Generator Exhaust Stack <sup>b</sup>		Product Gas Burner Stack <sup>c</sup>	
	lb/h	tons/yr	lb/h	tons/yr	lb/h	tons/yr
CO	2.4	3.99	10.4	3.12	1.7E-01	2.9E-01
NO <sub>x</sub>	4.0	6.65	48.4	14.50	1.1E-01	1.8E-01
SO <sub>x</sub>	0.02	0.03	3.2	0.95	4.2E-03	7.0E-03
PM <sub>10</sub>	0.2	0.36	3.4	1.02	3.0E-02	4.9E-02
HC	0.2	0.26	4.0	1.18	5.1E-02	8.4E-02

<sup>a</sup> Estimated on the basis of the utility requirements listed in Table 5.73.

<sup>b</sup> Based on 600 hours of operations per year.

<sup>c</sup> Estimate based on H<sub>2</sub> generation rate from steam reforming of natural gas.

during emergency diesel generator operation. Tables 5.80 and 5.81 summarize the TAP emission rates for the burning of natural gas in the boiler and fuel oil in the emergency diesel generator, respectively. Many of these emissions are also HAPs, as defined in Section 112 of the CAA, Title III. These TAP emission rates were estimated on the basis of the annual fuel consumption rates shown in Table 5.73 and with FIRE 6.22 emission factors for large wall-fired boilers with greater than 1,000 MMBtu/h of heat input and for reciprocating diesel engines (EPA 2000a). Daily emissions can be estimated from hourly emissions, assuming 12 hours of operation per day.

The neutralization/GPCR/TW-SCWO facility at BGAD would be equipped with building ventilation systems that would discharge, to the atmosphere, indoor air from the MDB process area, the Laboratory Building, and the Personnel and Maintenance Building through the filter farm stack. Of the three ventilation systems, only the indoor air from the MDB process area would be potentially exposed to chemical agents during operations.

To estimate the maximum potential emissions of chemical agents, only the MDB process area is considered to be a significant potential source. The filter systems would be designed to remove chemical agents from the ventilation air streams to levels below the allowable stack concentrations that have been recommended by the U.S. Department of Health and Human Services, Centers for Disease Control (53 *Federal Register* 8504 – 8507, March 15, 1988). Also, a negative pressure would be maintained at all times in the MDB after initiation of hot operations

**TABLE 5.80 Estimated Hourly and Annual TAP Emission Rates during Normal Boiler Operations for Neutralization/GPCR/TW-SCWO at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
2-Methylnaphthalene	6.9E-07	2.3E-03
3-Methylchloranthrene	5.2E-08	1.7E-04
Acenaphthene	5.2E-08	1.7E-04
Acenaphthylene	5.2E-08	1.7E-04
Anthracene	6.9E-08	2.3E-04
Arsenic	5.7E-06	1.9E-02
Barium	1.3E-04	4.2E-01
Benz(a)anthracene	5.2E-08	1.7E-04
Benzene	6.0E-05	2.0E-01
Benzo(a)pyrene	3.4E-08	1.1E-04
Benzo(b)fluoranthene	5.2E-08	1.7E-04
Benzo(g,h,i)perylene	3.4E-08	1.1E-04
Benzo(k)fluoranthene	5.2E-08	1.7E-04
Beryllium	3.4E-07	1.1E-03
Butane	6.0E-02	2.0E+02
Cadmium	3.2E-05	1.0E-01
Chromium	4.0E-05	1.3E-01
Chrysene	5.2E-08	1.7E-04
Cobalt	2.4E-06	8.0E-03
Copper	2.4E-05	8.1E-02
Dibenzo(a,h)anthracene	3.4E-08	1.1E-04
Dichlorobenzene	3.4E-05	1.1E-01
Dimethylbenz(a)anthracene	4.6E-07	1.5E-03
Ethane	8.9E-02	2.9E+02
Fluoranthene	8.6E-08	2.8E-04
Fluorene	8.0E-08	2.7E-04
Formaldehyde	2.2E-03	7.1E+00
Hexane(n)	5.2E-02	1.7E+02
Indeno(1,2,3-cd)pyrene	5.2E-08	1.7E-04
Lead	1.4E-05	4.7E-02
Manganese	1.1E-05	3.6E-02
Mercury	7.5E-06	2.5E-02
Molybdenum	3.2E-05	1.0E-01
Naphthalene	1.7E-05	5.8E-02
Nickel	6.0E-05	2.0E-01
Pentane(n)	7.5E-02	2.5E+02
Phenanthrene	4.9E-07	1.6E-03
Propane	4.6E-02	1.5E+02
Pyrene	1.4E-07	4.7E-04
Selenium	6.9E-07	2.3E-03
Toluene	9.7E-05	3.2E-01
Vanadium	6.6E-05	2.2E-01

<sup>a</sup> Emission factors from EPA (2000a).

**TABLE 5.81 Estimated Hourly and Annual TAP Emission Rates during Emergency Diesel Generator Operations for Neutralization/GPCR/TW-SCWO at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
Acenaphthene	3.1E-07	1.9E-04
Acenaphthylene	1.1E-06	6.7E-04
Acetaldehyde	1.7E-04	1.0E-01
Acrolein	2.0E-05	1.2E-02
Aldehydes	1.5E-02	9.2E+00
Anthracene	4.1E-07	2.5E-04
Benzene	2.0E-04	1.2E-01
Benzo(a)anthracene	3.7E-07	2.2E-04
Benzo(a)pyrene	4.1E-08	2.5E-05
Benzo(b)fluoranthene	2.2E-08	1.3E-05
Benzo(g,h,i)perylene	1.1E-07	6.4E-05
Benzo(k)fluoranthene	3.4E-08	2.0E-05
1,3-Butadiene	8.6E-06	5.1E-03
Chrysene	7.8E-08	4.6E-05
Dibenzo(a,h)anthracene	1.3E-07	7.7E-05
Fluoranthene	1.7E-06	1.0E-03
Fluorene	6.4E-06	3.8E-03
Formaldehyde	2.6E-04	1.6E-01
Indeno(1,2,3-cd)pyrene	8.2E-08	4.9E-05
Isomers of xylene	6.3E-05	3.7E-02
Mercury	6.6E-08	4.0E-05
Naphthalene	1.9E-05	1.1E-02
Phenanthrene	6.5E-06	3.9E-03
PAHs	3.7E-05	2.2E-02
Propylene	5.7E-04	3.4E-01
Pyrene	1.0E-06	6.3E-04
Toluene	9.0E-05	5.4E-02

<sup>a</sup> Emission factors from EPA (2000a).

to inhibit the release of chemical agents. Table 5.82 gives the potential chemical agent emission rates, assuming that the chemical agent concentrations in the air discharged from the filter form stack would be at 20% of the recommended allowable stack concentrations (i.e., the level of quantification of the ventilation exhaust chemical agent monitors.) These emissions calculations were based on actual operations time (12 hours per day, 276 days per year), since the only time there is a source of agent is during operations.

The estimated TAP emission rates (lb/h) during operations from the filter farm stack are provided in Tables 5.83 through 5.85 for GB, VX, and mustard agent processing, respectively.

**TABLE 5.82 Estimated Maximum Hourly and Annual Agent Emission Rates from the Filter Farm Stack for Neutralization/GPCR/TW-SCWO at BGAD**

Chemical Agent	Emission Factor (mg/m <sup>3</sup> ) <sup>a</sup>	Stack Exit Gas Flow (acfm) <sup>b</sup>	Hours of Operation per Year <sup>c</sup>	Stack Emission Rate	
				(lb/h)	(tons/yr) <sup>d</sup>
GB	0.00006	131,000	2,785	2.9E-05	4.1E-05
VX	0.00006	131,000	1,047	2.9E-05	1.5E-05
Mustard	0.006	131,000	194	2.9E-03	2.8E-04

<sup>a</sup> Based on the monitor level of quantification, which is 20% of the allowable stack concentration recommended for each chemical agent in 53 CFR 8504–8507.

<sup>b</sup> Filter farm stack exit flow modified from baseline incineration to account for 25% increase in building ventilation for the MDB.

<sup>c</sup> Hours of operations based on the assumption that each pilot plant operates at the design throughputs specified in CBDCOM (1997).

<sup>d</sup> Estimate based on the number of hours of operation per year.

Daily emission rates can be obtained by multiplying the hourly rates by 12. Annual emission rates can be estimated from the daily rates, assuming 232 operating days for GB (Table 5.83), 87 operating days for VX (Table 5.84), and 16 operating days for mustard agent (Table 5.85). Tables 5.86 through 5.88 give the corresponding estimated TAP emission rates from the process gas burner stack for GB, VX, and mustard agent, respectively.

Emissions from operations worker commuter vehicles were estimated on the basis of the assumption that each of the operations workers (721) would drive a round trip consisting of two 20-mi (32-km) one-way trips per day. Table 5.89 gives the annual emission estimates due to increased traffic.

**Liquid Wastes.** Through evaporation, crystallization, and filtration, brine salts would be formed from brine liquids from the TW-SCWO units. Remaining liquids would be recycled. Domestic sewage is the only major liquid effluent that is expected to be generated at the destruction facility. Small amounts of hazardous liquids could be generated from chemical makeup and reagents for support activities; the quantities are expected to be minor compared with domestic sewage (sanitary waste). Sanitary waste would be managed on-site.

**Solid Wastes.** The major process solid residuals expected from the neutralization/GPCR/TW-SCWO operation include the following:

**TABLE 5.83 Estimated TAP Emission Rates from the Filter Farm Stack during Neutralization/GPCR/TW-SCWO of ACW Containing GB Agent at BGAD<sup>a</sup>**

Compound	Emission Rate <sup>b</sup> (lb/h)	Compound	Emission Rate <sup>b</sup> (lb/h)
1,1,1-Trichloroethane	5.7E-13	Heptane, 3-ethyl-2-methyl-	1.4E-13
1,2,4-Trimethylbenzene	6.3E-14	Hexadecane, 2,6,10,14-tetramethyl-	2.6E-13
1H-Indene, 2,3-dihydro-	3.7E-13	Hexanal	8.3E-13
2-Methylnaphthalene	1.5E-13	HF	3.8E-04
2-Nitrophenol	4.1E-14	Iron	6.9E-12
9H-Fluoren-9-one	2.2E-11	Isobutyl alcohol	7.3E-13
Acenaphthene	7.3E-15	Lead	3.0E-13
Anthracene	8.2E-14	Magnesium	2.2E-11
Antimony	1.4E-14	Malonic acid	1.7E-10
Arsenic	5.5E-14	Manganese	9.7E-13
Benzaldehyde	2.3E-13	Mercury	1.3E-13
Benzene	1.0E-11	Methylene chloride	1.0E-09
Benzo(a)anthracene	1.6E-14	Molybdenum	3.6E-13
Beryllium	5.9E-15	m-Tolualdehyde	5.7E-13
Bis(2-ethylhexyl)phthalate	5.4E-14	Naphthalene	9.5E-13
Butanal	6.4E-14	Naphthalene, 1 methyl	1.5E-13
C3-Alkyl benzenes	3.9E-12	Nickel	2.0E-13
Cadmium	2.4E-14	Nitrobenzene	5.1E-13
Calcium	7.0E-11	Nonane, 2,6-dimethyl-	1.6E-13
Chrysene	3.2E-14	Pentanal	1.0E-12
Cobalt	7.7E-14	Phenanthrene	4.3E-13
Cyclohexane, butyl-	4.6E-14	Phenol	1.2E-13
Cyclohexanone	3.1E-13	Phosphorus	1.0E-10
Decane	5.1E-13	Propanal	7.7E-13
Decane, 2,6,7-trimethyl-	4.2E-14	p-Xylene	1.9E-13
Decane, 4-methyl-	5.5E-14	Pyrene	5.3E-14
Decane, 5-methyl-	1.9E-13	Silver	7.0E-14
Dibenzofuran	4.8E-13	Tetradecane	5.8E-13
Diphenylmethane	4.1E-14	Toluene	3.3E-12
Dodecane	9.3E-13	Tridecane	9.0E-13
Dodecane, 2,6,10-trimethyl-	5.8E-14	Undecane	8.4E-13
Dodecane, 4-methyl-	1.7E-13	Undecane, 2,10-dimethyl-	2.6E-13
Dodecane, 6-methyl-	1.0E-13	Undecane, 2,6-dimethyl-	3.2E-13
Ethanol, 2-(2-butoxyethoxy)-, acetate	2.0E-13	Undecane, 2-methyl-	2.0E-13
Ethanone, 1-(3-methylphenyl)-	6.2E-14	Vanadium	1.3E-14
Ethanone, 1-phenyl-	4.5E-13	Total HAPs	3.8E-04
Ethylene glycol	1.8E-12	CO	9.5E-02
Fluoranthene	9.8E-14	NO <sub>x</sub>	3.9E-10
Fluorene	1.8E-13	Particulates	3.9E-09
HCl	3.6E-11	SO <sub>2</sub>	5.4E-03
Heptadecane	1.4E-13	Total VOCs	2.0E-10
Heptanal	2.3E-12		

<sup>a</sup> Total campaign length of 232 operating days.

<sup>b</sup> Daily emission rates can be estimated on the basis of the assumption that there are 12 operating hours per day.

**TABLE 5.84 Estimated TAP Emission Rates from the Filter Farm Stack during Neutralization/GPCR/TW-SCWO of ACW Containing VX Agent at BGAD<sup>a</sup>**

Compound	Emission Rate (lb/h) <sup>b</sup>	Compound	Emission Rate (lb/h) <sup>b</sup>
1,2,4-Trimethylbenzene	1.7E-11	Lead	9.2E-11
1,4-Dichlorobenzene	3.9E-14	Magnesium	1.6E-10
1-Ethyl-2,2,6-trimethylcyclohexane	1.3E-11	Manganese	5.1E-10
2-(2-Butoxyethoxy) ethanol	1.5E-11	Methylene chloride	5.9E-12
2-Methylnaphthalene	6.2E-12	Molybdenum	1.8E-11
Acetic acid	4.7E-12	m-Tolualdehyde	4.2E-13
Anthracene	3.5E-14	Naphthalene	5.0E-12
Antimony	8.9E-12	Naphthalene, 1,2,3,4-tetrahydro-	8.2E-12
Benzene	1.1E-11	Naphthalene, 1,2,3,4-tetrahydro-6-methyl-	4.3E-12
Benzene, 1,2,3-trimethyl-	3.3E-12	Naphthalene, 1,7 dimethyl-	4.7E-12
Benzene, 1,2,4,5-tetramethyl-	1.6E-11	Nonane, 2,6-dimethyl-	4.0E-11
Benzene, 1-methyl-2-propyl-	1.5E-11	Nonane, 3,7-dimethyl-	5.8E-12
Benzene, 1-methyl-3-propyl-	3.7E-12	Nonane, 3-methyl-	3.0E-12
Benzyl alcohol	1.5E-11	Octane, 3,6-dimethyl-	1.4E-11
Bis(2-ethylhexyl)phthalate	5.3E-14	Pentadecane	9.7E-12
Butanal	2.5E-13	Phenanthrene	4.7E-13
Cadmium	2.5E-12	Phosphorus	1.7E-09
Calcium	5.8E-10	Potassium	7.7E-10
Cobalt	1.5E-12	Propanal	7.8E-13
Cyclohexane, 2-butyl-1,1,3-trimethyl-	2.9E-12	Pyrene	3.2E-14
Cyclohexane, butyl-	2.3E-11	Silver	5.5E-13
Cyclohexane, hexyl-	3.3E-12	Sodium	5.6E-10
Cyclohexanol	7.4E-12	Tetradecane	4.5E-11
Cyclohexanone	6.4E-14	Toluene	2.0E-12
Decane	9.4E-11	Tridecane	2.1E-11
Decane, 2-methyl-	2.2E-11	Tridecane, 2 methyl-	1.2E-11
Decane, 3-methyl-	1.6E-11	Tridecane, 4-methyl-	5.8E-12
Decane, 4-methyl-	1.2E-11	Tridecane, 6-propyl-	4.5E-12
Dibenzofuran	5.8E-13	Undecane	6.0E-11
Diethylene glycol	4.4E-11	Undecane, 2,10-dimethyl-	2.6E-12
Dodecane	3.7E-11	Undecane, 3,6-dimethyl-	9.3E-12
Dodecane, 6-methyl-	1.1E-11	Undecane, 4-methyl-	6.1E-12
Ethylene glycol	1.5E-11	Vanadium	9.0E-13
Fluoranthene	7.0E-14	Total HAPs	2.4E-04
Fluorene	2.0E-13	CO	1.6E-03
HCl	2.4E-04	NO <sub>x</sub>	1.4E-02
Heptane, 3-ethyl-2-methyl-	7.2E-12	Particulates	1.1E-07
Hexanal	8.8E-13	SO <sub>2</sub>	4.3E-03
Isobutyl alcohol	1.4E-11	Total VOCs	4.8E-10

<sup>a</sup> Total campaign length of 87 operating days.<sup>b</sup> Daily emission rates can be estimated on the basis of the assumption that there are 12 operating hours per day.

**TABLE 5.85 Estimated TAP Emission Rates from the Filter Farm Stack during Neutralization/GPCR/TW-SCWO of ACW Containing Mustard Agent at BGAD<sup>a</sup>**

Compound <sup>b</sup>	Emission Rate (lb/h) <sup>c</sup>	Compound <sup>b</sup>	Emission Rate (lb/h) <sup>c</sup>
(R)-(-)-2,2-dimethyl-1,3-dioxolane-4-methanol	7.1E-13	Manganese	5.2E-12
1-Propene, 3,3,3-trichloro-	1.2E-13	Methylene chloride	7.8E-12
2-Methylnaphthalene	1.9E-12	Molybdenum	3.3E-13
Acetaldehyde	1.6E-13	Naphthalene	2.7E-12
Acetone	1.0E-11	Nickel	5.0E-13
Arsenic	5.5E-14	n-Propylbenzene	3.8E-12
Benzaldehyde	7.1E-13	Octane, 2,6-dimethyl-	9.5E-12
Benzene	2.8E-12	Octane, 3-methyl-	3.5E-12
Benzyl alcohol	3.3E-13	Pentadecane	9.4E-14
Bis(2-ethylhexyl)phthalate	1.3E-13	Pentanal	2.3E-12
Butanal	1.2E-12	Phenanthrene	1.8E-14
C3-Alkyl benzenes	6.1E-11	Phosphorus	9.2E-12
Cadmium	4.3E-14	Potassium	1.8E-11
Calcium	1.4E-10	p-Xylene	8.5E-12
Chromium	8.5E-14	Selenium	1.1E-13
Cobalt	8.2E-13	Silver	1.3E-14
Cyclohexane, butyl-	5.3E-12	Sulfur, mol. (S8)	2.9E-12
Cyclohexane, propyl-	6.1E-12	Tetradecane	5.6E-12
Cyclohexanone	4.4E-13	Total HpCDD	9.7E-19
Cyclohexasiloxane, dodecamethyl-	2.3E-13	Total HxCDD	4.4E-19
Decane	2.5E-11	Total PeCDD	9.0E-18
Decane, 3-methyl-	6.3E-12	Total PeCDF	5.6E-19
Decane, 4-methyl-	8.4E-14	Total TCDD	5.5E-17
Dodecane	9.8E-12	Total TCDF	5.1E-18
Dodecane, 6-methyl-	9.6E-14	Tridecane	6.7E-12
Ethanol, 2-(2-butoxyethoxy)-, acetate	4.0E-13	Undecane	1.7E-11
Ethylene glycol	3.9E-12	Vanadium	9.8E-15
HCl	8.8E-03	Zinc	1.1E-12
Heptanal	2.9E-12	Total HAPs	1.3E-05
Hexanal	7.4E-13	NO <sub>x</sub>	2.1E-03
Iron	1.2E-11	Particulates	1.8E-09
Lead	4.5E-13	SO <sub>2</sub>	1.2E-02
Magnesium	4.0E-11	Total VOCs	3.6E-10
Malonic acid	1.8E-10		

<sup>a</sup> Total campaign length of 16 operating days.

<sup>b</sup> Abbreviations: HpCDD = heptachlorodibenzo-p-dioxin; HxCDD = hexachlorodibenzo-p-dioxin; PeCDD = pentachlorodibenzo-p-dioxin; PeCDF = pentachlorodibenzo-p-furan; TCDD = tetrachlorodibenzo-p-dioxin; and TCDF = tetrachlorodibenzo-p-furan.

<sup>c</sup> Daily emission rates can be estimated on the basis of the assumption that there are 12 operating hours per day.



**TABLE 5.86 Estimated TAP Emission Rates from the Product Gas Burner Stack during Neutralization/GPCR/TW-SCWO of ACW Containing GB Agent at BGAD<sup>a</sup>**

Compound <sup>b</sup>	Emission Rate (lb/h) <sup>c</sup>	Compound <sup>b</sup>	Emission Rate (lb/h) <sup>c</sup>
1,1,1-Trichloroethane	6.6E-07	HF	1.0E-05
1,2,3,4,6,7,8-HpCDF	1.0E-13	Hydrogen cyanide	4.0E-05
1,2,3,4,7,8-HxCDF	7.9E-13	Hydrogen sulfide	5.9E-02
1,2,3,6,7,8-HxCDF	3.0E-13	Iron	9.9E-05
1-Hexanol, 2-ethyl-	2.0E-04	Lead	1.2E-06
1H-Indene	5.0E-05	Magnesium	2.3E-05
2,3,7,8-TCDF	4.7E-13	Manganese	2.2E-04
2,4-Dimethylphenol	2.0E-05	Methylene chloride	7.9E-05
2-Butanone	7.0E-06	Molybdenum	6.5E-04
Acetone	1.8E-03	Naphthalene	1.1E-06
Aluminum	6.8E-05	Nickel	9.5E-06
Antimony	2.3E-07	Nitrobenzene	3.4E-06
Arsenic	3.2E-06	Phenol	2.9E-05
Barium	3.0E-06	Phosphorus	4.4E-05
Benzaldehyde	7.0E-05	Selenium	1.3E-06
Benzaldehyde, 4-ethyl-	1.6E-05	Silver	8.0E-07
Benzaldehyde, ethyl-	9.7E-06	Sodium	2.0E-03
Benzaldehyde, ethyl-benzenemethanol, 4-(1-methylethyl)-	9.1E-06	Styrene	4.1E-06
Benzene	4.9E-05	Tetrachloroethene	5.9E-07
Benzo(a)anthracene	5.4E-07	Thallium	2.9E-07
Benzyl alcohol	1.3E-05	Tin	1.2E-05
Beryllium	5.8E-08	Toluene	6.6E-06
Bis(2-ethylhexyl)phthalate	1.5E-05	Total HpCDF	1.1E-14
Cadmium	9.1E-07	Total HxCDD	5.9E-12
Calcium	1.5E-04	Total HxCDF	1.2E-11
Carbon disulfide	1.9E-06	Total PeCDD	3.4E-12
Chloroform	3.0E-05	Total PeCDF	4.2E-12
Chromium	8.2E-06	Total TCDD	2.8E-12
Cobalt	2.7E-07	Total TCDF	5.9E-12
Copper	1.5E-05	Trichloroethene	5.9E-07
Cyclododecane	2.2E-05	Vanadium	8.7E-07
Cyclotetrasiloxane, octamethyl-	2.2E-05	Xylenes	3.1E-06
Dibenzofuran	7.8E-06	Zinc	1.2E-05
Diethylphthalate	1.3E-05	Total dioxins/furans	1.7E-12
Di-n-butylphthalate	2.8E-05	CO	3.2E-03
Dodecane	8.6E-06	NO <sub>x</sub>	2.0E-01
Ether	1.5E-03	Particulates	7.4E-02
Ethylbenzene	4.5E-05	SO <sub>2</sub>	9.0E-03
Fluorene	3.6E-07	Total VOCs	3.0E-03
HCl	5.8E-04	Total HAPs	6.1E-02
Hexane	9.2E-04		

<sup>a</sup> Total campaign length of 232 operating days.

<sup>b</sup> Abbreviations: HpCDF = heptachlorodibenzo-p-furan; HxCDF = hexachlorodibenzo-p-furan.

<sup>c</sup> Daily emission rates can be estimated on the basis of the assumption that there are 12 operating hours per day.

**TABLE 5.87 Estimated TAP Emission Rates from the Product Gas Burner Stack during Neutralization/GPCR/TW-SCWO of ACW Containing VX Agent at BGAD<sup>a</sup>**

Compound	Emission Rate (lb/h) <sup>b</sup>	Compound	Emission Rate (lb/h) <sup>b</sup>
1,1,1-Trichloroethane	6.7E-07	Magnesium	2.3E-05
1-Hexanol, 2-ethyl-	2.1E-04	Manganese	2.3E-04
1H-Indene	5.2E-05	Methylene chloride	8.1E-05
2,4-Dimethylphenol	2.0E-05	Molybdenum	6.6E-04
2-Butanone	7.2E-06	Naphthalene	1.2E-06
Acetone	1.8E-03	Nickel	9.7E-06
Aluminum	6.9E-05	Nitrobenzene	3.5E-06
Antimony	2.3E-07	Phenol	3.0E-05
Arsenic	3.2E-06	Phosphorus	4.5E-05
Barium	3.0E-06	Selenium	1.3E-06
Benzaldehyde	7.2E-05	Silver	8.2E-07
Benzaldehyde, 4-ethyl-	1.6E-05	Sodium	2.0E-03
Benzaldehyde, ethyl-	1.0E-05	Styrene	4.2E-06
Benzaldehyde, ethyl-benzenemethanol, 4-(1-methylethyl)-	9.3E-06	Tetrachloroethene	6.1E-07
Benzene	5.0E-05	Thallium	3.0E-07
Benzo(a)anthracene	5.5E-07	Tin	1.2E-05
Benzyl alcohol	1.3E-05	Toluene	6.7E-06
Beryllium	5.9E-08	Trichloroethene	6.1E-07
Bis(2-ethylhexyl)phthalate	1.5E-05	Vanadium	8.9E-07
Cadmium	9.3E-07	Xylenes	3.1E-06
Calcium	1.6E-04	Zinc	1.2E-05
Carbon disulfide	2.0E-06	1,2,3,4,6,7,8-HpCDF	1.0E-13
Chloroform	3.0E-05	1,2,3,4,7,8-HxCDF	8.1E-13
Chromium	8.4E-06	1,2,3,6,7,8-HxCDF	3.0E-13
Cobalt	2.8E-07	2,3,7,8-TCDF	4.8E-13
Copper	1.6E-05	Dibenzofuran	8.0E-06
Cyclododecane	2.2E-05	Total HpCDF	1.2E-11
Cyclotetrasiloxane, octamethyl-	2.2E-05	Total HxCDD	6.0E-12
Diethylphthalate	1.3E-05	Total HxCDF	1.2E-11
Di-n-butylphthalate	2.8E-05	Total PeCDD	3.4E-12
Dodecane	8.8E-06	Total PeCDF	4.3E-12
Ether	1.5E-03	Total TCDD	2.8E-12
Ethylbenzene	4.6E-05	Total TCDF	6.1E-12
Fluorene	3.6E-07	Total dioxins/furans	1.7E-12
HCl	5.9E-04	CO	3.2E-03
Hexane	9.4E-04	NO <sub>x</sub>	1.7E-01
HF	1.0E-05	Particulates	7.5E-02
Hydrogen cyanide	4.1E-05	SO <sub>2</sub>	4.9E-03
H <sub>2</sub> S	6.0E-02	Total VOCs	3.1E-03
Iron	1.0E-04	Total HAPs	6.2E-02
Lead	1.2E-06		

<sup>a</sup> Total campaign length of 87 operating days.<sup>b</sup> Daily emission rates can be estimated on the basis of the assumption that there are 12 operating hours per day.

**TABLE 5.88 Estimated TAP Emission Rates from the Product Gas Burner Stack during Neutralization/GPCR/TW-SCWO of ACW Containing Mustard Agent at BGAD<sup>a</sup>**

Compound	Emission Rate (lb/h) <sup>b</sup>	Compound	Emission Rate (lb/h) <sup>b</sup>
1,1,1-Trichloroethane	6.1E-07	Iron	9.1E-05
1,2,3,4,6,7,8-HpCDF	9.4E-14	Lead	5.4E-07
1,2,3,4,7,8-HxCDF	7.3E-13	Magnesium	1.7E-05
1,2,3,6,7,8-HxCDF	2.7E-13	Manganese	6.3E-05
1-Hexanol, 2-ethyl-	1.9E-04	Methylene chloride	4.9E-06
1H-Indene	4.6E-05	Molybdenum	4.4E-06
2,3,7,8-TCDF	4.3E-13	Nickel	8.7E-06
2,4-Dimethylphenol	1.8E-05	Phenol	3.4E-06
2-Butanone	6.4E-06	Phosphorus	3.3E-05
Acetone	1.7E-04	Selenium	1.2E-06
Aluminum	6.2E-05	Silver	1.1E-07
Arsenic	4.6E-07	Sodium	1.7E-03
Barium	2.7E-06	Styrene	3.8E-06
Benzaldehyde, 4-ethyl-	1.5E-05	Tetrachloroethene	5.4E-07
Benzaldehyde, ethyl-	9.0E-06	Tin	1.1E-05
Benzaldehyde, ethyl-benzenemethanol, 4-(1-methylethyl)-	8.3E-06	Toluene	6.1E-06
Benzene	4.3E-05	Total HpCDF	1.0E-11
Benzyl alcohol	8.6E-06	Total HxCDD	5.4E-12
Bis(2-ethylhexyl)phthalate	3.4E-06	Total HxCDF	1.1E-11
Cadmium	9.0E-08	Total PeCDD	3.1E-12
Calcium	1.2E-04	Total PeCDF	3.8E-12
Carbon disulfide	1.8E-06	Total TCDD	2.5E-12
Chloroform	2.7E-05	Total TCDF	5.5E-12
Chromium	7.5E-06	Trichloroethene	5.4E-07
Cobalt	2.4E-07	Vanadium	2.1E-07
Copper	5.1E-06	Xylenes	2.8E-06
Cyclotetrasiloxane, octamethyl-	2.0E-05	Zinc	1.1E-05
Diethylphthalate	1.2E-05	Total dioxins/furans	1.5E-12
Di-n-butylphthalate	2.5E-05	Total HAPs	6.3E-04
Dodecane	7.9E-06	CO	2.4E-03
Ethylbenzene	6.1E-07	NO <sub>x</sub>	2.0E-01
HCl	2.0E-04	Particulates	5.2E-02
HF	9.3E-06	SO <sub>2</sub>	1.1E-03
Hydrogen cyanide	3.7E-05	Total VOCs	3.8E-04
H <sub>2</sub> S	9.0E-05		

<sup>a</sup> Total campaign length of 16 operating days<sup>b</sup> Daily emission rates can be estimated assuming 12 operating hours per day.

**TABLE 5.89 Estimated Emissions from Worker Commuter Vehicles during Neutralization/GPCR/TW-SCWO Operations at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Emission Rate (tons/yr)
HC	199,000	1.16	20	16.4
CO	199,000	11.38	20	160.7
NO <sub>x</sub>	199,000	0.73	20	10.3
SO <sub>x</sub>	199,000	0.12	20	1.7
PM <sub>10</sub>	199,000	0.055	20	0.78

<sup>a</sup> Number of auto round trips to the operation site estimated on the basis of the total operating personpower and an assumption of 276 days of operations per year.

<sup>b</sup> Emission factors determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and EPA PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

- Scrap metal and other solid residues decontaminated to a 5X condition in the GPCR, a thermal system that uses hydrogen in a steam atmosphere to reduce organics into CH<sub>4</sub>, CO<sub>2</sub>, CO, and acid gases;
- Brine salts from treatment of the SCWO effluent; and
- TRBP residues.

The brine salts (filter cake) would be transported to an approved off-site hazardous waste treatment, storage, and disposal facility for additional treatment and/or ultimate disposal. Table 5.90 shows the composition of the filter cake and the rate of generation per processing day for processing of ACW containing GB, VX, and mustard agent. Tables 5.91 and 5.92 show the corresponding information for the processing of TRBP residues and 5X scrap metal.

These waste streams would be shipped from the on-site facility to off-site locations. Tables 5.93 through 5.95 provide transportation data for annual shipment of these waste streams for mustard, GB, and VX agent processing, on the basis of 16 days of operation for mustard agent, 232 days for GB agent, and 87 days for VX agent.

#### 5.3.4.4 Activities

The PMACWA described the activities for installation of the neutralization/GPCR/TW-SCWO system (PMACWA 2001b). Table 5.96 shows the major phases of the project.

**TABLE 5.90 Estimated Generation Rates of Brine Salts from Neutralization/GPCR/TW-SCWO at BGAD To Be Sent Off-Site for Land Disposal**

Compound	Generation Rate (lb/d)		
	GB Agent	VX Agent	Mustard Agent
Aluminum	6.3E+01	6.2E+01	6.3E+00
Antimony	0.0E+00	1.3E-02	0.0E+00
Arsenic	4.3E-02	3.5E-03	3.6E-03
Barium	3.7E-03	1.5E-03	0.0E+00
Beryllium	5.4E-04	4.3E-04	0.0E+00
Cadmium	1.2E-04	0.0E+00	0.0E+00
Calcium	0.0E+00	0.0E+00	8.5E-02
Calcium silicate	4.1E+00	5.0E+00	0.0E+00
Chloride	0.0E+00	6.1E+00	0.0E+00
Chromium	6.3E-03	6.4E-03	3.3E-02
Cobalt	7.3E-04	1.3E-03	0.0E+00
Copper	4.2E-03	3.5E-03	3.1E-03
Cyanide	2.3E-03	7.0E-03	0.0E+00
Fluoride	0.0E+00	3.1E+00	1.9E+00
Iron	1.5E-01	7.3E-02	1.5E-01
Lead	2.3E+01	2.1E+01	6.4E-03
Magnesium	2.4E-02	8.1E-03	2.2E-02
Manganese	1.7E-03	1.1E-03	1.5E-03
Mercury	1.9E-04	2.8E-03	1.4E-04
Molybdenum	4.0E-03	0.0E+00	4.3E-03
Nickel	4.9E-02	3.3E-02	3.8E-02
Nitrate-N	3.8E+00	6.5E+00	4.9E+00
Nitrite-N	5.3E+00	1.2E+01	5.2E+00
Phosphorus	7.7E+01	1.4E+01	2.7E+01
Potassium	8.5E-01	1.0E+01	1.2E+00
Silver	1.3E-03	0.0E+00	7.0E-03
Sodium chloride	0.0E+00	0.0E+00	6.8E+03
Sodium fluoride	7.5E+02	0.0E+00	0.0E+00
Sodium phosphate	1.8E+04	1.6E+04	2.8E+02
Sodium sulfate	0.0E+00	1.5E+03	1.7E+04
Sulfide	0.0E+00	3.9E-01	3.6E+02
Sulfur	0.0E+00	0.0E+00	2.9E+02
Thallium	1.3E-03	1.8E-03	2.5E-02
Vanadium	0.0E+00	0.0E+00	1.2E-03
Water in salt cake	2.9E+03	2.6E+03	3.6E+03
Zinc	4.1E-02	9.3E-03	2.1E-03
Total	2.2E+04	2.0E+04	2.8E+04
Operating days	232	87	16

**TABLE 5.91 Estimated Generation Rates of TRBP Residues from Neutralization/GPCR/TW-SCWO at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)		
	GB Agent	VX Agent	Mustard Agent
2-Pentanone, 4-hydroxy-4-methyl-	1.1E-01	3.1E-01	4.7E+00
3-Hexen-1-ol	0.0E+00	0.0E+00	1.1E-01
3-Hexene, 2,2,5,5-tetramethyl-, (Z)-	0.0E+00	0.0E+00	2.2E-01
Aluminum	2.2E+02	6.2E+02	4.9E+01
Antimony	1.1E-05	9.6E-06	0.0E+00
Arsenic	3.2E-02	9.0E-02	0.0E+00
Barium	1.0E-05	9.4E-06	1.5E+01
Beryllium	1.8E-03	5.2E-03	0.0E+00
Bis(2-ethylhexyl)phthalate	0.0E+00	0.0E+00	8.9E-02
Calcium	0.0E+00	0.0E+00	8.8E+02
Calcium silicate	3.2E-04	3.8E-04	0.0E+00
Chloride	1.1E+01	3.2E+01	0.0E+00
Chromium	8.9E-02	2.5E-01	0.0E+00
Cobalt	9.2E-03	2.6E-02	0.0E+00
Copper	3.0E-02	8.6E-02	1.1E+00
Cyanide	1.6E-02	4.5E-02	6.9E-01
Cyanide, reactive	6.3E-01	1.8E+00	2.7E+01
Cyclohexane, 1-methyl-3-propyl-	0.0E+00	0.0E+00	8.2E-02
Cyclohexanone	0.0E+00	0.0E+00	1.6E-01
Disodium phosphate	2.5E+01	1.6E+01	0.0E+00
Eicosane	0.0E+00	0.0E+00	1.2E-01
Fluoride	0.0E+00	1.3E+00	1.7E+00
Hexacosane	0.0E+00	0.0E+00	8.2E-02
Hexatriacontane	0.0E+00	0.0E+00	8.2E-02
Iron	4.3E+00	1.2E+01	2.4E+01
Lead	2.3E-01	2.1E-01	0.0E+00
Magnesium	1.1E+01	3.1E+01	0.0E+00
Manganese	7.4E-01	2.1E+00	3.2E+01
Mercury	4.3E-03	1.2E-02	1.8E-01
Naphthalene	1.6E-03	4.5E-03	6.9E-02
Nickel	5.2E-02	1.5E-01	0.0E+00
Nitrate-N	4.1E-02	1.2E-01	1.2E+00
Nitrite-N	2.4E-02	6.8E-02	1.0E+00
Octadecanoic acid, butyl ester	2.5E-02	7.2E-02	0.0E+00
o-Phosphate-P	0.0E+00	0.0E+00	5.1E-01
Pentadecane	0.0E+00	0.0E+00	1.1E-01
Pentanal, 2-methyl-	0.0E+00	0.0E+00	1.3E-01
Phosphorus	1.1E+00	3.0E+00	0.0E+00
Potassium	9.2E+01	0.0E+00	4.0E+03
Sodium chloride	0.0E+00	0.0E+00	6.8E+01
Sodium fluoride	7.6E+00	0.0E+00	0.0E+00

**TABLE 5.91 (Cont.)**

Compound	Generation Rate (lb/d)		
	GB Agent	VX Agent	Mustard Agent
Sodium sulfide	1.0E-05	8.2E+00	9.3E+01
Sulfate	2.3E-01	6.5E-01	5.1E+00
Tetracosane	0.0E+00	0.0E+00	8.2E-02
Unknown alcohol	0.0E+00	1.4E-01	2.1E+00
Unknown alkane	3.3E-02	9.5E-02	0.0E+00
Unknown amide	1.9E-02	5.4E-02	8.2E-01
Unknown amine	3.8E-02	1.1E-01	0.0E+00
Vanadium	6.6E-02	1.9E-01	0.0E+00
Zinc	3.5E+00	1.0E+01	0.0E+00
Total	3.8E+02	7.4E+02	5.2E+03
Operating days	232	87	16

**TABLE 5.92 Estimated Generation Rates of 5X Metals from Neutralization/GPCR/TW-SCWO at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)		
	GB Agent	VX Agent	Mustard Agent
Aluminum	9.0E+02	8.8E+02	5.8E+01
Aluminum oxide	5.1E+03	4.7E+03	0.0E+00
Carbon (from wood and resin)	9.1E+02	9.4E+02	9.0E+02
Copper	6.9E+01	1.5E+02	1.8E+03
Glass fiber	8.6E+02	7.8E+02	0.0E+00
Steel/iron	8.2E+03	1.8E+04	7.8E+04
Zinc	6.3E+00	1.5E+01	3.2E+02
Total	1.6E+04	2.5E+04	8.1E+04
Operating days	232	87	16

**TABLE 5.93 Transportation Data for Solid Wastes from Neutralization/GPCR/TW-SCWO of ACW Containing Mustard Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3
Transported materials			
Type/chemical	Brine salts – waste	TRBP residue – waste	5X solids – waste
Physical form	Solid	Solid	Solid
Chemical composition/ temperature, pressure	See Table 5.90	See Table 5.91	See Table 5.92
Packaging			
Type <sup>a</sup>	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	50	50
Material weight (lb)	1,070	520	450
Chemical content (wt%)	See Table 5.90	See Table 5.91	See Table 5.92
Shipments			
Average weight (tons/yr) <sup>b</sup>	226	42	1,306
Average volume (ft <sup>3</sup> /yr)	3,130	1,210	43,430
Packages/yr	426	165	5,907
Packages/shipment	36	48	48
Shipments/yr	12	4	124
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Destination - facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

<sup>b</sup> Annual estimates based on a campaign length of 16 days.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.



**TABLE 5.94 Transportation Data for Solid Wastes from Neutralization/  
GPCR/TW-SCWO of ACW Containing GB Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3
Transported materials			
Type/chemical	Brine salts – waste	TRBP residue – waste	5X solids – waste
Physical form	Solid	Solid	Solid
Chemical composition/ temperature, pressure	See Table 5.90	See Table 5.91	See Table 5.92
Packaging			
Type <sup>a</sup>	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	50	50
Material weight (lb)	760	980	450
Chemical content (wt%)	See Table 5.90	See Table 5.91	See Table 5.92
Shipments			
Average weight (tons/yr) <sup>b</sup>	2,562	44	3,031
Average volume (ft <sup>3</sup> /yr)	49,980	660	100,810
Packages/yr	6,798	90	13,712
Packages/shipment	48	36	48
Shipments/yr	142	3	286
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Destination - facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the 5X solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

<sup>b</sup> Annual estimates based on a campaign length of 232 days.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

**TABLE 5.95 Transportation Data for Solid Wastes from Neutralization/GPCR/TW-SCWO of ACW Containing VX Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3
Transported materials			
Type/chemical	Brine salts – waste	TRBP residue – waste	5X solids – waste
Physical form	Solid	Solid	Solid
Chemical composition/ temperature, pressure	See Table 5.90	See Table 5.91	See Table 5.92
Packaging			
Type <sup>a</sup>	55-gal drum	55-gal drum	55-gal drum
Container Volume (ft <sup>3</sup> )	7.35	7.35	7.35
Certified by	DOT	DOT	DOT
Identifier	Varies	Varies	Varies
Container weight (lb)	50	50	50
Material weight (lb)	770	1,220	450
Chemical content (wt%)	See Table 5.90	See Table 5.91	See Table 5.92
Shipments			
Average weight (tons/yr) <sup>b</sup>	885	32	1,939
Average volume (ft <sup>3</sup> /yr)	16,910	390	64,490
Packages/yr	2,300	54	8,772
Packages/shipment	48	32	48
Shipments/yr	48	2	183
Form of transport/routing			
Form of transportation	Truck	Truck	Truck
Destination - facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the 5X solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

<sup>b</sup> Estimated on the basis of a campaign length of 87 days.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

**TABLE 5.96 Activities for Neutralization/  
GPCR/TW-SCWO at BGAD**

Key Milestones
EIS start
Start of EDS-II testing
PMACWA programmatic EIS submittal
PMACWA programmatic ROD submittal
DOD technology decision
RCRA Part B and CAA permits approval
MDB construction start
MDB construction completion
Systemization/pilot test start
Systemization/pilot test completion
Operations start
Operations completion

Source: PMACWA (2001b).

#### 5.3.4.5 Uncertainties

As indicated earlier, each of the individual technologies that form the neutralization/GPCR/TW-SCWO system has either been previously proven to be a successful technology or has been demonstrated by the PMACWA to be an acceptable technology for application at BGAD. However, demonstration testing focused on individual technologies and sometimes used less than full-scale units. In addition, although EDSs were conducted to evaluate the long-term adequacy of individual technologies, it was not possible to evaluate the long-term viability and performance of the entire, integrated treatment system. Thus, the primary uncertainty associated with neutralization/GPCR/TW-SCWO is that the entire, integrated treatment system, with all its component units, has not been assembled and tested. The pilot program, if implemented for this technology system, would be designed to evaluate overall operability and long-term performance.

#### 5.3.5 ELECTROCHEMICAL OXIDATION

This description of the electrochemical oxidation technology system is based on several primary reports. A description of the proposed technology system can be found in the technology developer's demonstration report (AEA/CH2MHILL 2000) and is referred to by its developers as "SILVER II." In addition, as indicated in that report, many of the estimates provided for facility design and operation refer comparatively to the U.S. Army baseline incineration process, which indicates, in general, that estimates are comparable to those associated with the baseline incineration process. Thus, another of the primary sources of information for this section of the TRD is the EIS for disposal of chemical agents and munitions stored at Pine Bluff Arsenal,

Arkansas (PMCD 1997). That is the most recent EIS that the U.S. Army has prepared for baseline incineration of chemical munitions.

In addition to the above, mass balance estimates, air emission estimates, and solid waste estimates for application of the electrochemical oxidation technology at BGAD (Mitretek 2001d) have been developed. Air emissions and solid waste estimates for electrochemical oxidation, as discussed below, are based on Mitretek inputs, along with appropriate assumptions on filtration systems and plant operations schedule.

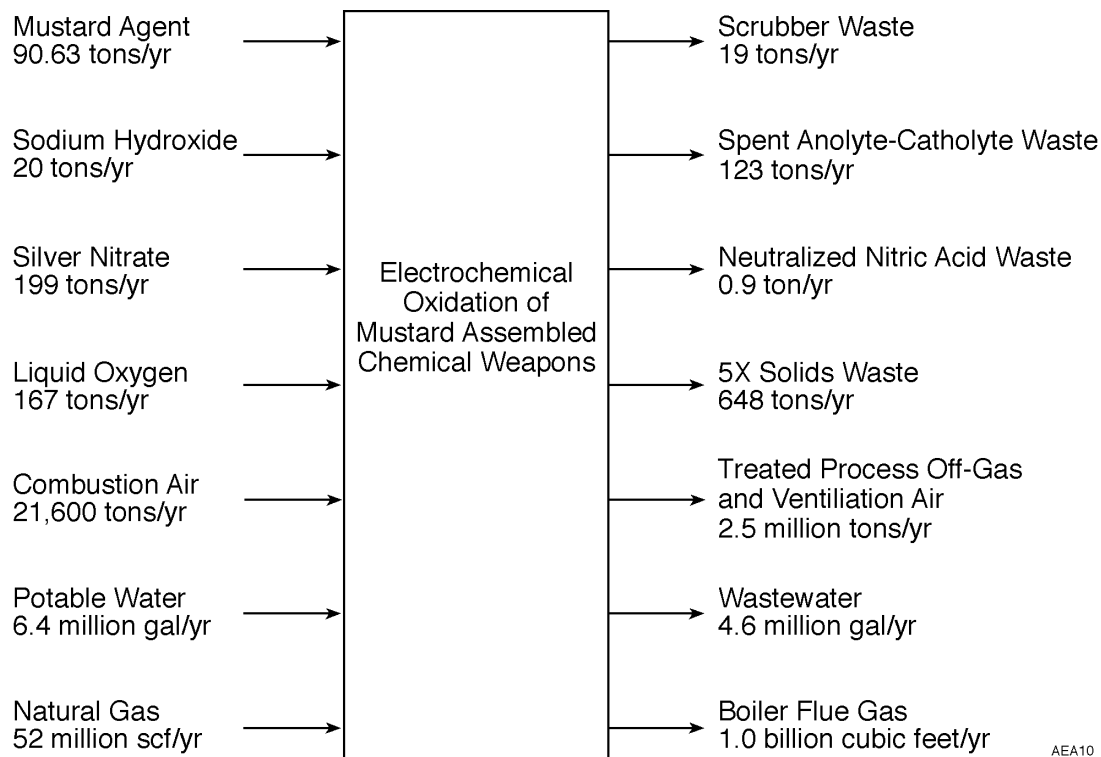
Many of the figures and tables referred to in the facility description for this technology system contain estimates (e.g., emissions, resources consumed) associated with processing ACW with a specified agent; these estimates are given on an annual basis (e.g., tons per year). In some cases, these estimates have been converted from other units (e.g., lb/d) by accounting for the number of days of operation required for processing a specific type of ACW. This period of time is referred to as a campaign. Campaigns are agent-specific. The values in many of the following figures and tables are based on the number of days in the campaign required to process ACW containing mustard, GB, and VX agent. It was assumed that there are 276 days of operation in a year. If the campaign is less than or equal to 276 days, annual quantities equal total quantities. If the campaign is greater than 276 days, quantities in the figures and tables are for 276 days of processing. In the latter case, the estimates provided are less than total quantities. Daily (or other) quantities may be obtained by adjusting for the number of days in the campaign.

Figures 5.41 through 5.43 provide input/output material balances for the major streams for electrochemical oxidation of ACW containing mustard, GB, and VX agent, respectively. The amounts of air, potable water, natural gas input, treated off-gas, ventilation air, wastewater, and boiler flue gas shown in each of these figures represent total annual amounts.

### **5.3.5.1 General Facility Description**

The proposed electrochemical oxidation facility is designed to fit approximately into the same space and general configuration as the baseline incineration process. The physical plant is expected to consist of a two-story building constructed of noncombustible materials, with a concrete structural frame and a low-slope concrete roof.

The site layout for the electrochemical oxidation facility is shown in Figures 5.44 through 5.46. Figure 5.44 shows the general facility layout, Figure 5.45 shows the layout of the first floor of the MDB, and Figure 5.46 shows the layout of the second floor. Additional diagrams may be found in AEA/CH2MHILL (2000). In addition, AEA/CH2MHILL (2000) provides descriptions of the various units and operations that are to be included in each section of the building, as shown in Figures 5.44 through 5.46.

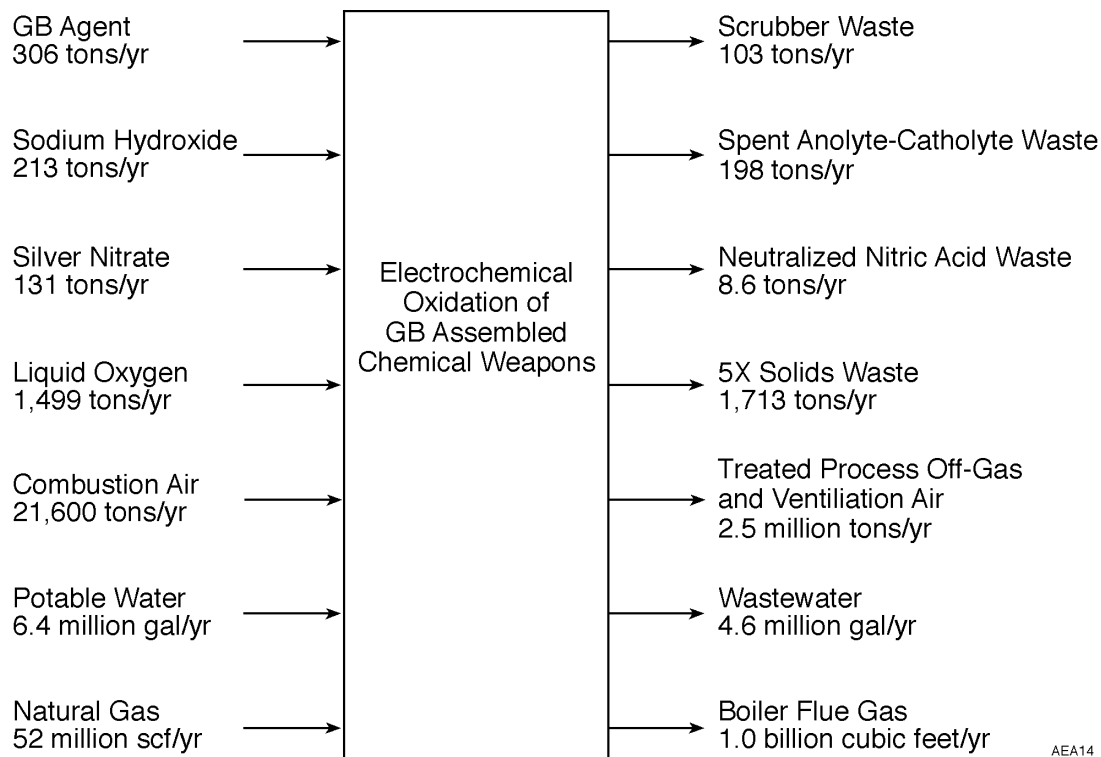


**FIGURE 5.40 Input/Output Material Balance for Electrochemical Oxidation of ACW Containing Mustard Agent at BGAD**

### 5.3.5.2 Construction Phase

The schedule for destruction of the stockpile at BGAD, although tentative, calls for construction of the selected alternative to begin following issuance of the EIS ROD and receipt of the RCRA permit and any other environmental permits, as necessary. It is anticipated that the construction schedule for the electrochemical oxidation facility would be similar to that of the baseline incineration facility. Construction would take approximately 30 months (PMACWA 2001b), and would include a 2-month design and procurement verification period. However, the PMACWA is investigating means of shortening the construction phase.

Construction of the destruction facility at BGAD would result in consumption of materials and resources, vehicle exhaust emissions, fugitive dust, noise, destruction of wildlife habitat and native vegetation, increased employment, increased demand for public services, and occupational health hazards.



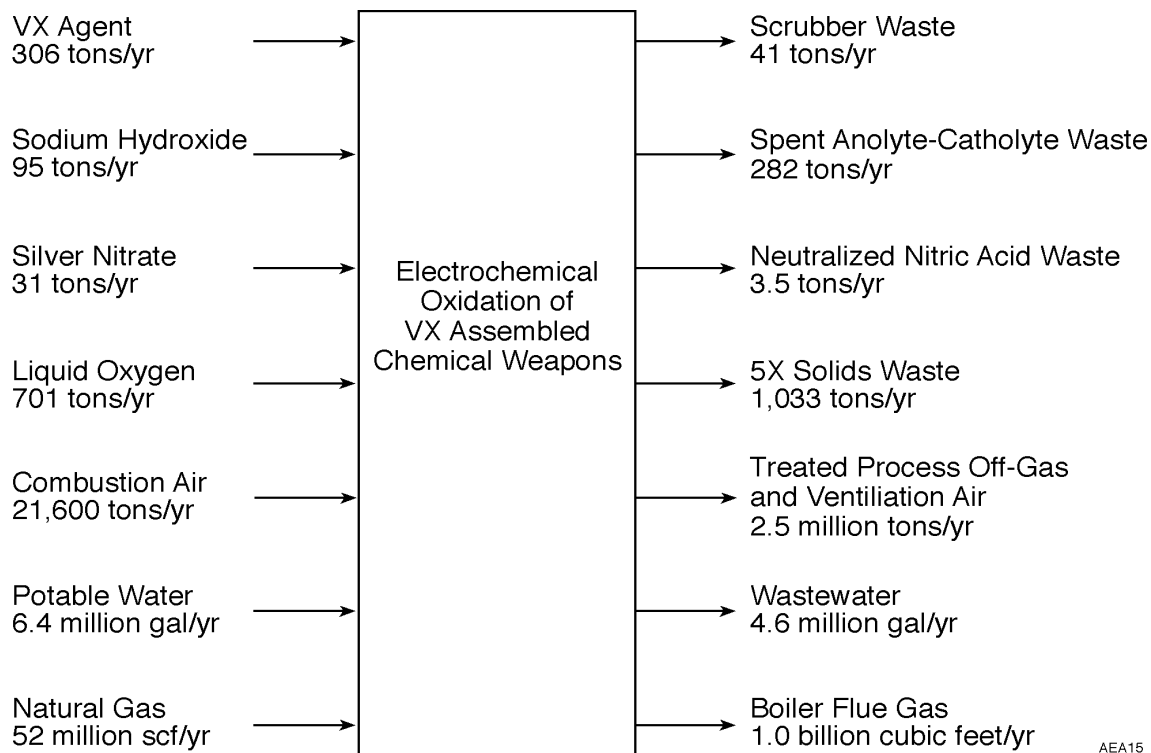
**FIGURE 5.41 Input/Output Material Balance for Electrochemical Oxidation of ACW Containing GB Agent at BGAD**

#### 5.3.5.2.1 Construction Inputs and Resource Requirements

Resources and materials needed for construction of the destruction facility would include water, electricity, structural and piping steel, concrete, vehicle fuel, and industrial gases (propane). Table 5.97 contains order-of-magnitude estimates of the materials and resources that would be consumed during construction. These estimates are based on material and resource estimate methodologies used in engineering analyses and environmental documents concerning DOE's waste management activities. For example, estimates of 20 gal (76 L) of water for each construction FTE and solidification requiring 26 lb (12 kg) of water for each 100 lb (45 kg) of cement are from DOE (1997). More precise estimates would require a detailed consideration of construction activities.

Process equipment would use some materials that are also used in construction, such as steel. However, the amount of such material used for process equipment is expected to be small compared to that used in building construction and is not considered in Table 5.97.

Table 5.98 gives order-of-magnitude estimates of the number of shipments of construction material to the site. These estimates do not include shipments of process and related



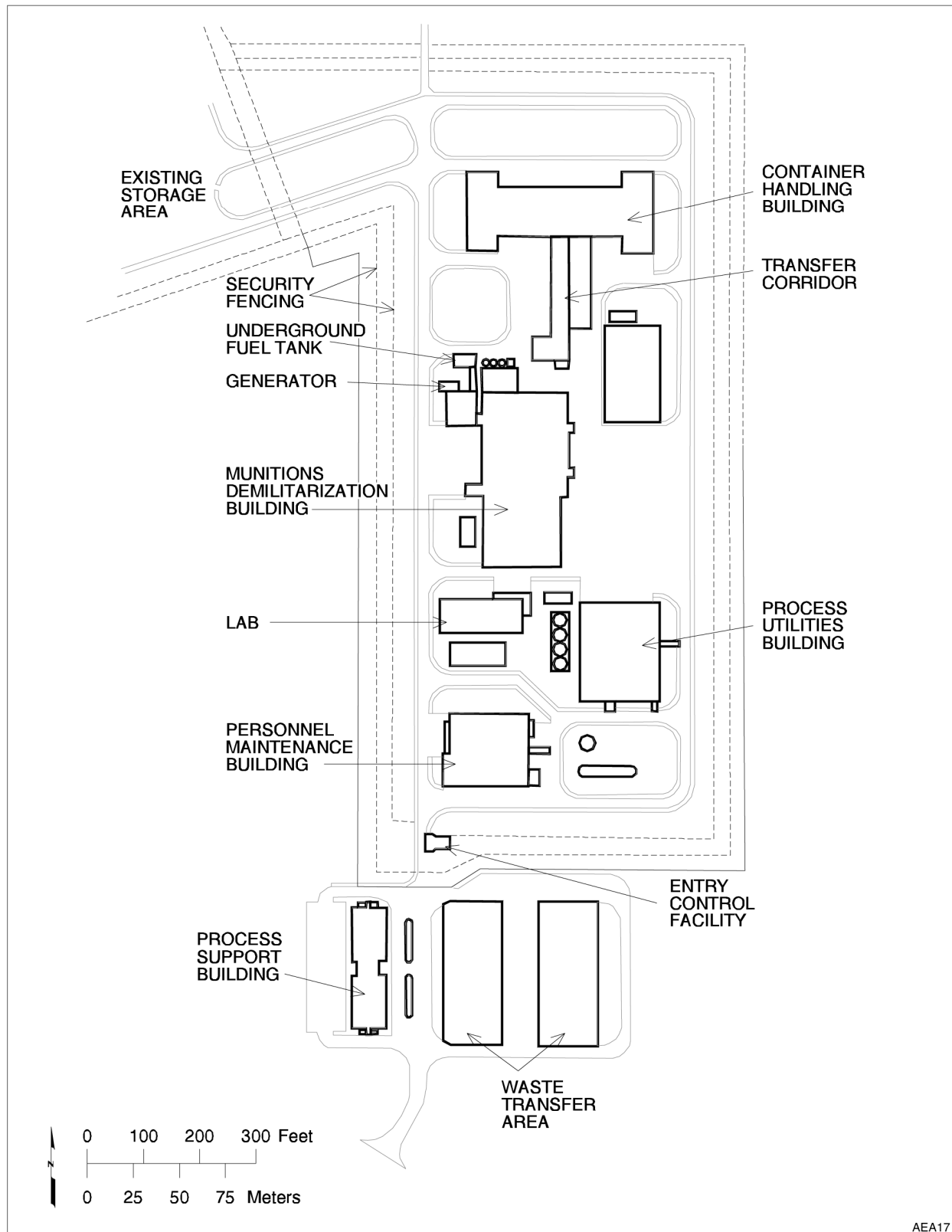
**FIGURE 5.42 Input/Output Material Balance for Electrochemical Oxidation of ACW Containing VX Agent at BGAD**

equipment, the number of which is expected to be small compared to the number of shipments of construction material. It was assumed that constituents of cement and backfill would be shipped in end-dump trucks with a capacity of 10 yd<sup>3</sup> (8 m<sup>3</sup>), that steel would be shipped on trucks with a 21-ton (19-t) net payload, and that liquid fuel would be shipped in tank trucks with a nominal capacity of 9,000 gal (34,000 L).

Order-of-magnitude estimates of emissions of criteria pollutants from construction delivery vehicles are provided in Table 5.99. It was assumed that the delivery vehicles would be heavy-duty diesel trucks and that the length of a one-way trip would be 20 mi (32 km) (roughly equal to the distance to the outskirts of Lexington, Kentucky). Actual trip distances would depend on a number of factors, including the availability of construction materials from local distributors and the distance of the site from the distributors.

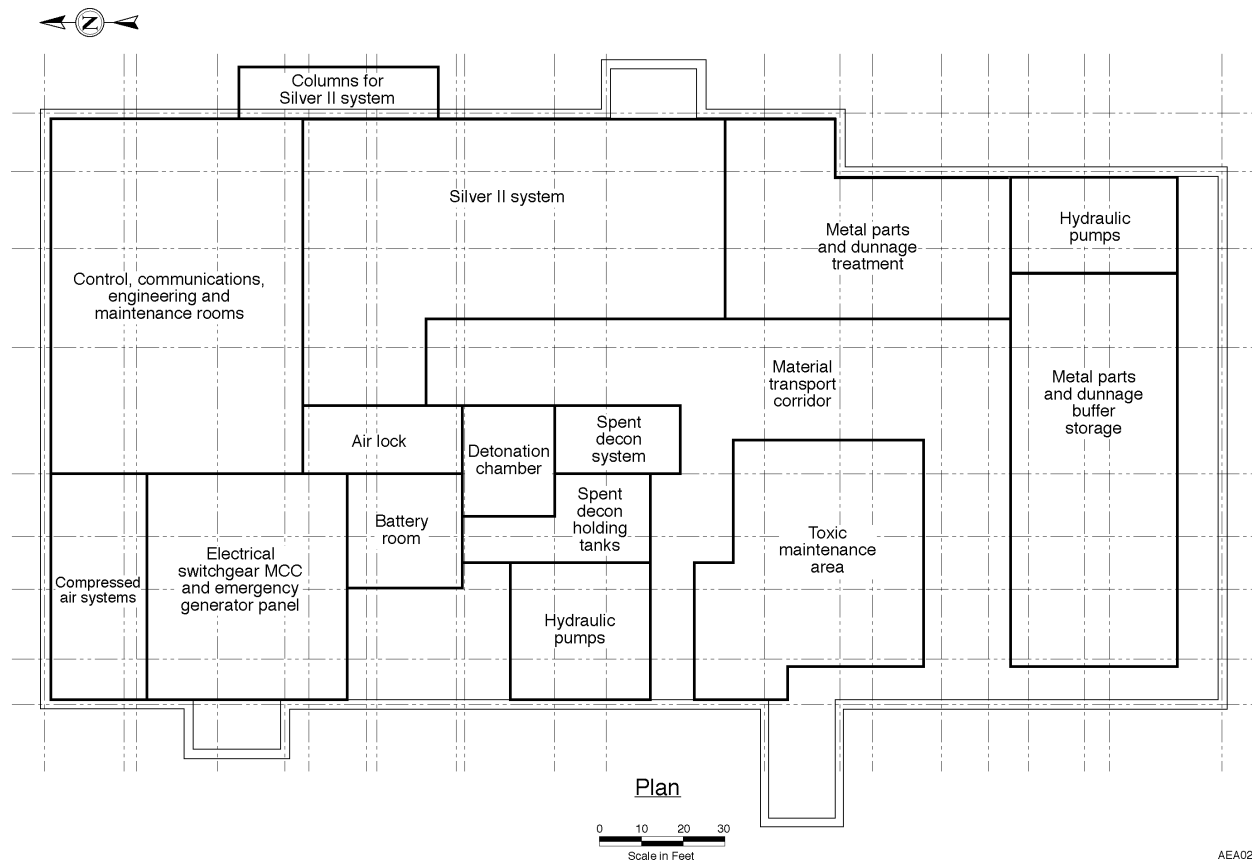
#### 5.3.5.2.2 Construction Workforce

The construction workforce is expected to increase steadily to a peak of about 1,000 FTEs near the midpoint of the 30-month construction period, and then to decrease steadily until construction is completed. The average number of construction workers per month would



**FIGURE 5.43** Electrochemical Oxidation Facility Layout at BGAD (Source: Adapted from AEA/CH2MHILL 2000)



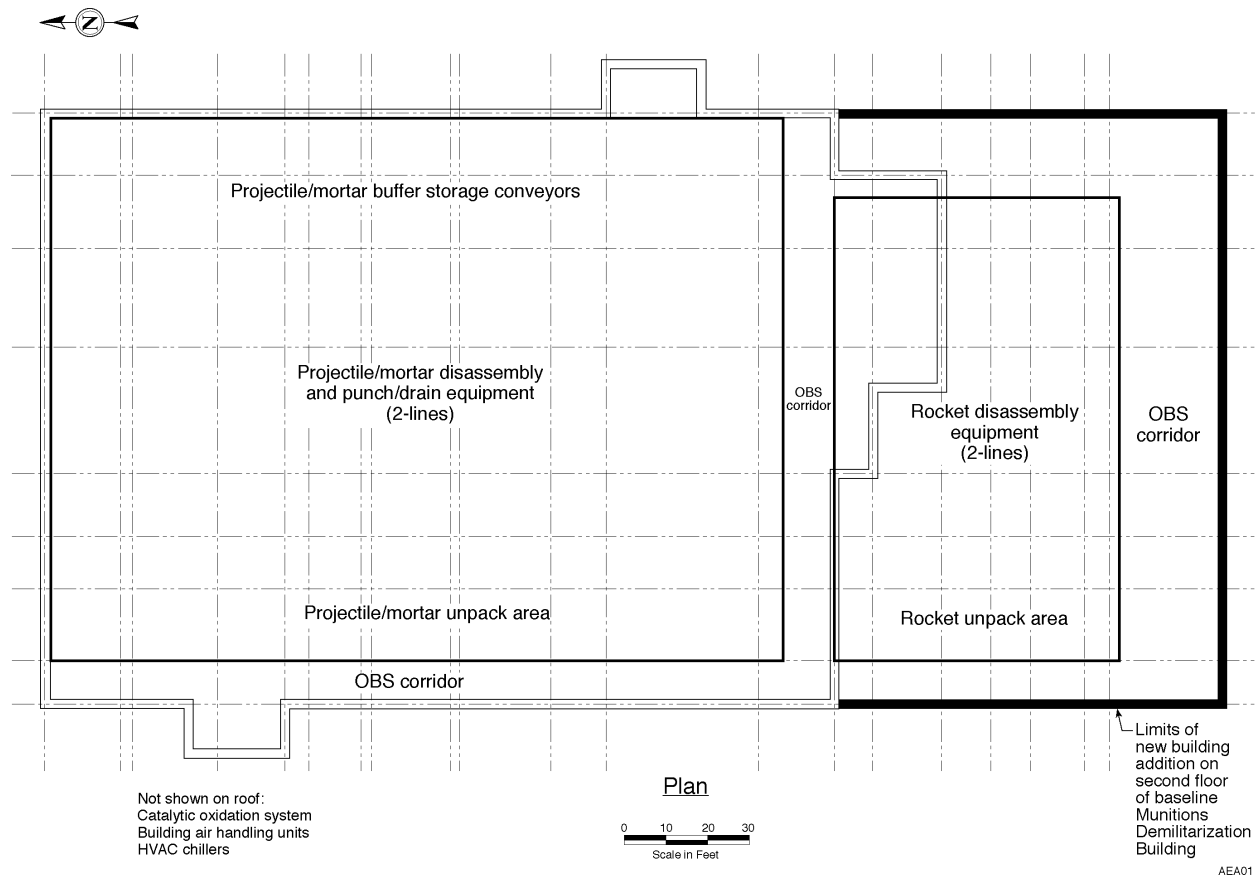


**FIGURE 5.44 Layout of First Floor of the Munitions Demilitarization Building for the Electrochemical Oxidation Facility at BGAD (Source: Adapted from AEA/CH2MHILL 2000)**

be approximately 550 FTEs. The total effort during construction is estimated to be approximately 1,200 FTE years. These estimates were developed from an activity-based approach that considered the various types of buildings, required instrumentation, process equipment installation, and other related construction activities. Table 5.100 provides an estimate of the employment buildup by year during construction.

### 5.3.5.2.3 Construction Emissions and Waste Estimates

During the construction phase, fugitive emissions would consist mainly of dust and vehicle exhaust. Temporary, regional increases in atmospheric concentrations of CO, NO<sub>x</sub> hydrocarbons, particulate matter, and SO<sub>x</sub> would result from the exhaust emissions of commuter vehicles, heavy construction vehicles, diesel generators, and other machinery and tools. Annual emissions of these pollutants would be small in comparison to de minimis levels typically used by regulators to determine whether an air quality permit or impact analysis is necessary. Emissions from construction vehicles are exempt from permit requirements. Nevertheless, vehicles would be equipped with standard pollution control devices to minimize air quality impacts.



**FIGURE 5.45 Layout of Second Floor of the Munitions Demilitarization Building for the Electrochemical Oxidation Facility at BGAD (Source: Adapted from AEA/CH2MHILL 2000)**

Estimated emissions from construction activities (not including emissions from delivery vehicles) are shown in Table 5.101. The emissions shown are based on the anticipated construction land disturbance and vehicle traffic (for dust particulate pollutants) and fuel and gas consumption. The column marked “Total” indicates the estimated total amount of emissions that would occur over the entire construction period.

Emissions from construction worker commuter vehicles were estimated on the basis of the assumption that an average of about 550 automobiles (one car per construction worker) would be added to the area. As with construction delivery vehicles, it was assumed that a one-way trip in a commuter vehicle would be 20 mi (32 km) in length. Table 5.102 gives the estimated annual emissions of criteria pollutants arising from these trips.

Additional emissions would result from the use of paints and thinners, aerosols, and other area source emissions. These emissions are expected to be minor contributors to air pollution and were not included in current estimates.

**TABLE 5.97 Estimated Materials/Resources Consumed during Construction of an Electrochemical Oxidation Facility at BGAD<sup>a</sup>**

Construction Material/Resource	Total Consumption	Peak Demand
Utilities		
Water <sup>b</sup>	9,000,000 gal	NA <sup>c</sup>
Electricity <sup>c</sup>	57,000 MWh	3.1 MW
Solids		
Concrete	33,400 yd <sup>3</sup>	NA
Steel	6,600 tons	NA
Piping	120,000 linear feet	NA
Liquids		
Fuel <sup>d</sup>	2,500,000 gal	NA
Gases		
Industrial gases (propane) <sup>d</sup>	6,600 gal	NA

<sup>a</sup> All values can be considered order-of-magnitude approximations of the actual values; more accurate values would require a detailed consideration of construction activities.

<sup>b</sup> Water requirement estimate is based on DOE (1997), in which each FTE required 20 gal/d, and solidification required 26 lb per 100 lb of cement.

<sup>c</sup> NA = not applicable.

<sup>d</sup> Scaling method based on Folga et al. (1999).

Construction would generate solid wastes primarily in the form of excavation spoils and building material debris. These latter wastes would include concrete forms, equipment and hardware containers and packaging, paint cans, waste metal sheeting, pipe and wire, and landscaping debris. Small amounts of liquid wastes, such as solvents, cleaning solutions, and paint wastes, also would be generated. Wastes would be collected and disposed of in compliance with U.S. Army, federal, state, and local requirements. All construction debris would be removed from the site for disposal. Any batteries, used motor oils, and empty containers would be separated from the waste streams and recycled. Any wastes that are identified as hazardous would be stored and disposed of per RCRA requirements. Sanitary wastes are the only significant liquid effluents that would be generated during construction and would be managed on-site.

Table 5.103 gives the estimated total quantities of solid and liquid wastes generated from activities associated with facility construction. The waste generation quantities are based on historic data on land area size and the construction labor force.

**TABLE 5.98 Order-of-Magnitude Estimate of the Number of Truck Shipments of Construction Materials during Construction of an Electrochemical Oxidation Facility at BGAD<sup>a</sup>**

Resource	Total Consumption	Truck Capacity	No. Truck Shipments
Portland cement <sup>b</sup>	3,674 yd <sup>3</sup>	10 yd <sup>3</sup>	384
Gravel <sup>b</sup>	13,694 yd <sup>3</sup>	10 yd <sup>3</sup>	1,431
Sand <sup>b</sup>	8,684 yd <sup>3</sup>	10 yd <sup>3</sup>	908
Steel <sup>c</sup>	6,600 tons	21 tons	280
Asphalt paving <sup>d</sup>	1,200 tons	20 tons	60
Backfill <sup>e</sup>	12,800 yd <sup>3</sup>	10 yd <sup>3</sup>	1,140
Fuel <sup>f</sup>	2,500,000 gal	9,000 gal	290
Total			4,547
Total (rounded up)			5,000

<sup>a</sup> The calculation did not include truck deliveries of process equipment and related items.

<sup>b</sup> Assumes that concrete is composed of 11% portland cement, 41% gravel, and 26% sand and is shipped to the site in a standard 10-yd<sup>3</sup> end-dump truck.

<sup>c</sup> Assumes that the net payload for steel transport to the site is 42,000 lb.

<sup>d</sup> Assumes HMA is loaded into 20-ton-capacity triaxle trucks for transport to the paving site.

<sup>e</sup> Assumes shipment is in standard 10-yd<sup>3</sup> end-dump trucks and no fill material is available on-site.

<sup>f</sup> Assumes shipment using DOT 406/MC-306 atmospheric pressure tank truck with a 9000-gal capacity.

### 5.3.5.3 Operations Phase

Information on the operations phase of facility operations is presented in this section. Pre-operational testing is discussed first, followed by facility inputs and resource requirements, workforce requirements, and emissions and waste estimates.

**TABLE 5.99 Estimated Emissions from Delivery Vehicles during Construction of an Electrochemical Oxidation Facility at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Construction Period (yr)	Emission Rate (tons/yr)
HC	5,000	2.12	20	2.4	0.3
CO	5,000	11.28	20	2.4	1.6
NO <sub>x</sub>	5,000	1.25	20	2.4	0.2
SO <sub>x</sub>	5,000	0.23	20	2.4	0.03
PM <sub>10</sub>	5,000	0.617	20	2.4	0.1

<sup>a</sup> Number of auto round trips to the construction site estimated on the basis of the total number of deliveries.

<sup>b</sup> Emission factors determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and EPA PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

**TABLE 5.100 Estimated Number of Construction Employees Needed by Year for Construction of an Electrochemical Oxidation Facility at BGAD**

Employees	Year 1	Year 2	Year 3
Total craft workers	360	650	100
Construction management and support staff	90	160	20
Total	450	810	120

**TABLE 5.101 Estimated Emissions during Construction of an Electrochemical Oxidation Facility at BGAD**

Criteria Pollutant	Total (tons)	Annual (tons/yr)
CO	125	50
HC	52	21
NO <sub>x</sub>	185	74
SO <sub>x</sub>	13	5
Particulates	523	209

**TABLE 5.102 Estimated Emissions from Worker Commuter Vehicles during Construction of an Electrochemical Oxidation Facility at BGAD**

Criteria Pollutant	No. of Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-Way Trip Distance (mi) <sup>c</sup>	Emission Rate (tons/yr)
HC	133,000	1.16	20	10.9
CO	133,000	11.38	20	107.0
NO <sub>x</sub>	133,000	0.73	20	6.9
SO <sub>x</sub>	133,000	0.12	20	1.1
PM <sub>10</sub>	133,000	0.055	20	0.5

<sup>a</sup> Number of auto round trips to the construction site estimated on the basis of the average construction workforce and an assumption of 240 workdays per year.

<sup>b</sup> Emission factors determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

### 5.3.5.3.1 Preoperational Testing

A preoperational testing period assumed to last 14 months would begin following facility construction (PMACWA 2001b). Often referred to as systemization, this period would include preoperational checkout, training, and integrated systems operation under mock conditions with simulated munitions filled with surrogate chemicals (PMCD 1997). Systemization would be used to ensure that systems are operating as designed prior to pilot-scale operations. Therefore, it would appear that no hazardous emissions or effluents would be generated. The only types of effluents that would be generated would be criteria pollutants (during testing of the steam boilers and the emergency diesel generator) and sanitary waste (from the systemization workforce). The amounts of criteria pollutants released and sanitary wastes generated would be negligible compared with those during construction and operations; thus, they were not considered in this analysis. It is projected that 315 contractor FTE-years would be needed for systemization.

### 5.3.5.3.2 Operations Inputs and Resource Requirements

At full-scale operation, destruction of the ACW containing mustard agent at BGAD is projected to require 16 days for processing, and destruction of the ACW containing nerve agents would require 319 days for processing (232 for GB and 87 for VX). Destruction operations at BGAD are projected to require approximately 15.5 months at full-scale operation (see Table 5.104). This duration is based on a 12-hours-per-day, 6-days-per-week operation, 4 weeks per month, with two 3-week munitions changeover periods.

**TABLE 5.103 Estimated Total Wastes Generated during Construction of an Electrochemical Oxidation Facility at BGAD**

Waste Category	Quantity
Hazardous solids	100 yd <sup>3</sup>
Hazardous liquids	39,000 gal
Nonhazardous solids	
Concrete <sup>a</sup>	220 yd <sup>3</sup>
Steel <sup>b</sup>	33 tons
Other <sup>c</sup>	1,800 yd <sup>3</sup>
Nonhazardous liquids	
Sanitary <sup>d</sup>	5,600,000 gal
Other	2,500,000 gal

<sup>a</sup> Amount of concrete (nonhazardous solid) waste estimated by assuming that 0.65% of concrete usage is spoilage.

<sup>b</sup> Amount of steel waste stream estimated as 0.5% of steel requirement on the basis of LLNL et al. (1997).

<sup>c</sup> Amount of other stream estimated as eight times the concrete stream on the basis of LLNL et al. (1997).

<sup>d</sup> Amount of sanitary waste estimated on the basis of the total construction workforce.

**TABLE 5.104 Inventory and Estimated Processing Time for Electrochemical Oxidation of ACW Stored at BGAD**

Munition	Quantity	Agent	Processing Rate (no. of munitions/h)	Processing Time		Changeover (weeks)	Total (weeks)
				Hours	Weeks <sup>a</sup>		
155-mm projectile	15,492	H	80	194	2.7	0.0	2.7
8-in. projectile	3,977	GB	20	199	2.8	3.0	5.8
M55 rocket	51,716	GB	20	1,586	35.9	0.0	35.9
155-mm projectile	12,816	VX	80	160	2.2	3.0	5.2
M55 rocket	17,733	VX	20	887	12.3	0.0	12.3
Total	101,734			4,025	55.9	6.0	61.9

<sup>a</sup> Estimated by assuming 6-days-per-week operations, 12 hours per day.

Estimated annual utility consumption for facility operation, including electricity, fuel, and potable water usage, is presented in Table 5.105. The estimates in Table 5.105 are based on the assumption that the facility would consume potable water and produce sanitary waste 365 days per year. These are conservative assumptions that would identify an upper bound to potable water and sanitary waste treatment requirements. It was also assumed conservatively that fuel oil would be consumed only by an emergency diesel generator that would operate 600 hours per year. This analysis assumed that the amount of natural gas consumed for space heating would be negligible compared to the amount of natural gas consumed during the electrochemical oxidation process.

Materials would be consumed by the destruction processes. Table 5.106 gives the amounts of  $\text{AgNO}_3$ ,  $\text{HNO}_3$  (VX process only), calcium nitrate ( $\text{CaN}_2\text{O}_6$ ) (mustard and GB processing only), LOX, and NaOH that would be consumed during the processing of the three agents.

Tables 5.107 through 5.109 present estimated transportation data using the input material streams from Mitretek (2001d) for these raw materials for mustard processing, GB processing, and VX processing, respectively. Liquid NaOH, solid  $\text{AgNO}_3$ , and  $\text{CaN}_2\text{O}_6$  would be transported in 55-gal (208-L) drums. Liquid oxygen would be transported in bulk by tanker truck, and liquid  $\text{HNO}_3$  would be transported in railcars.

#### **5.3.5.3.3 Operations Workforce**

The electrochemical oxidation facility would be a government-owned, contractor-operated facility. Contractor employees would handle plant operations, while government employees would handle munitions, provide security, and staff other support activities. It is estimated that 721 FTE-years (571 FTE-years of contractor employee effort and 150 FTE-years of government employee effort) would be needed.

#### **5.3.5.3.4 Operations Emissions and Waste Estimates**

Wastes from the electrochemical oxidation process would include air emissions, solid wastes, and liquid wastes. The only liquid effluents expected from the facility would be dilute, neutralized  $\text{HNO}_3$ , which would be accepted by a publicly owned treatment works (POTW), and sanitary waste, which would be managed in an on-site treatment unit. All other liquids generated by the process and all liquid laboratory wastes would be reused in the process or destroyed internally by the electrochemical oxidation process. Destruction facility operations, including waste management, would comply with U.S. Army, federal, state, and local requirements. Any wastes that are identified as hazardous (such as possibly evaporator bottoms) would be stored and disposed of in compliance with RCRA requirements. Silver salts would be processed off-site for silver recovery after being treated to a 5X condition.



**TABLE 5.105 Estimated Utilities Consumed during Destruction of ACW at the Electrochemical Oxidation Facility at BGAD**

Utility	Average Daily Consumption	Peak-Day Consumption	Annual Consumption
Process water <sup>a</sup>	3,700 gal/d	208 gal/h	18,000,000 gal/yr
Potable water <sup>b</sup>	17,500 gal/d	180 gal/min	6,400,000 gal/yr <sup>c</sup>
Fire water <sup>b</sup>	NA <sup>d</sup>	3,000 gal/min	NA
Sanitary sewer <sup>b</sup>	20,650 gal/d	395 gal/min	7,500,000 gal/yr <sup>c</sup>
Natural gas <sup>a</sup>	188,000 scf/d	218,000 scf/d	52,000,000 scf/yr <sup>c</sup>
Fuel oil	962 gal/d	406 gal/h	48,000 gal/yr <sup>f</sup>
Electricity	144 MWh	21.8 MW	122.4 GWh <sup>c,g</sup>

<sup>a</sup> Estimated on the basis of the munitions processing rate and unit utility factors for the electrochemical oxidation technology.

<sup>b</sup> Assumed to be similar to incineration because the number of operations and maintenance personnel and land area are unchanged from incineration.

<sup>c</sup> Based on 365 days of operation per year.

<sup>d</sup> NA = not applicable.

<sup>e</sup> Based on 276 days of operations per year.

<sup>f</sup> Estimated on the basis of 600 hours of emergency diesel generator operation per year.

<sup>g</sup> Based on an average power rating of 80%.

Source: PMCD (1997).

**TABLE 5.106 Estimated Raw Materials Consumed Annually during Normal Electrochemical Oxidation Operations at BGAD<sup>a</sup>**

Agent Processed	Material	Average Daily Consumption (lb/d)	Annual Consumption (tons/yr)
Mustard, nominal 16-day campaign	AgNO <sub>3</sub>	25,000	200
	HNO <sub>3</sub>	0	0
	CaN <sub>2</sub> O <sub>6</sub>	11,600	93
	Oxygen	20,000	170
	NaOH	2,400	20
GB, nominal 232-day campaign	AgNO <sub>3</sub>	1,130	130
	HNO <sub>3</sub>	0	0
	CaN <sub>2</sub> O <sub>6</sub>	1,600	180
	Oxygen	13,000	1,500
	NaOH	1,800	210
VX, nominal 87-day campaign	AgNO <sub>3</sub>	713	31
	HNO <sub>3</sub>	36	1.6
	CaN <sub>2</sub> O <sub>6</sub>	0	0
	Oxygen	16,000	700
	NaOH	2,187	95

<sup>a</sup> Estimated on the basis of a nominal campaign length for the respective agent.

Source: Mitretek (2001d).

**TABLE 5.107 Transportation Data for Raw Materials for Electrochemical Oxidation of ACW Containing Mustard Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	AgNO <sub>3</sub>	CaN <sub>2</sub> O <sub>6</sub>	LOX	HNO <sub>3</sub>
Physical form	Liquid	Solid	Solid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	AgNO <sub>3</sub> / ambient	CaN <sub>2</sub> O <sub>6</sub> / ambient	O <sub>2</sub> /-297°F, 1 atm	HNO <sub>3</sub> / ambient
Packaging					
Type	55-gal drum	55-gal drum	55-gal drum	4,000-gal tanker truck	11,000-gal railcar
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	535	1,470
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	NA <sup>a</sup>	NA
Material weight (lb) <sup>b</sup>	700	2,000	1,090	38,080	107,000
Chemical content (wt%)	50% NaOH	100% AgNO <sub>3</sub>	100% CaN <sub>2</sub> O <sub>6</sub>	100% O <sub>2</sub>	50% HNO <sub>3</sub>
Shipments					
Average weight (tons/yr) <sup>c</sup>	20	199	93	167	0
Average volume (ft <sup>3</sup> /yr)	415	1,468	1,267	4,684	0
Packages/yr	57	200	173	9	0
Packages/shipment	48	20	36	1	1
Shipments/yr	2	10	5	9	0
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Railcar
Specific gravity (77°F)	NA	4.352	2.36	1.1407	1.30

<sup>a</sup> NA = not applicable.<sup>b</sup> Based on Mitretek (2001d).<sup>c</sup> Annual estimates based on 16 days for processing ACW containing mustard agent.

**TABLE 5.108 Transportation Data for Raw Materials for Electrochemical Oxidation of ACW Containing GB Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	AgNO <sub>3</sub>	CaN <sub>2</sub> O <sub>6</sub>	LOX	HNO <sub>3</sub>
Physical form	Liquid	Solid	Solid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	AgNO <sub>3</sub> / ambient	CaN <sub>2</sub> O <sub>6</sub> / ambient	O <sub>2</sub> /-297°F, 1 atm	HNO <sub>3</sub> / ambient
Packaging					
Type	55-gal drum	55-gal drum	55-gal drum	4,000-gal tanker truck	11,000-gal railcar
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	535	1,470
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	NA <sup>a</sup>	NA
Material weight (lb) <sup>b</sup>	700	2,000	1,090	38,080	107,000
Chemical content (wt%)	50% NaOH	100% AgNO <sub>3</sub>	100% CaN <sub>2</sub> O <sub>6</sub>	100% O <sub>2</sub>	50% HNO <sub>3</sub>
Shipments					
Average weight (tons/yr) <sup>c</sup>	213	131	180	1,499	0
Average volume (ft <sup>3</sup> /yr)	4,518	965	2,447	42,086	0
Packages/yr	615	132	333	79	0
Packages/shipment	48	20	36	1	1
Shipments/yr	13	7	10	79	0
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Railcar
Specific gravity (77°F)	NA	4.352	2.36	1.1407	1.30

<sup>a</sup> NA = not applicable.<sup>b</sup> Based on Mitretek (2001d).<sup>c</sup> Estimated on the basis of a campaign length of 232 operating days.

**TABLE 5.109 Transportation Data for Raw Materials for Electrochemical Oxidation of ACW Containing VX Agent at BGAD**

Type of Data	Input Material No. 1	Input Material No. 2	Input Material No. 3	Input Material No. 4	Input Material No. 5
Transported materials					
Type/chemical	NaOH	AgNO <sub>3</sub>	CaNO <sub>6</sub>	LOX	HNO <sub>3</sub>
Physical form	Liquid	Solid	Solid	Liquid	Liquid
Chemical composition/ temperature, pressure	NaOH/ ambient	AgNO <sub>3</sub> / ambient	CaN <sub>2</sub> O <sub>6</sub> / ambient	O <sub>2</sub> /-297°F, 1 atm	HNO <sub>3</sub> / ambient
Packaging					
Type	55-gal drum	55-gal drum	55-gal drum	4,000-gal tanker truck	11,000-gal railcar
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	535	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	NA <sup>a</sup>	50
Material weight (lb) <sup>b</sup>	700	2,000	1,090	38,080	600
Chemical content (wt%)	50% NaOH	100% AgNO <sub>3</sub>	100% CaN <sub>2</sub> O <sub>6</sub>	100% O <sub>2</sub>	50% HNO <sub>3</sub>
Shipments					
Average weight (ton/yr) <sup>c</sup>	95	31	0	701	1.6
Average volume (ft <sup>3</sup> /yr)	2,027	229	0	19,683	39
Packages/yr	276	32	0	37	6
Packages/shipment	48	20	36	1	1
Shipments/yr	6	2	0	37	6
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Railcar
Specific gravity (77°F)	NA	4.352	2.36	1.1407	1.30

<sup>a</sup> NA = not applicable.<sup>b</sup> Based on Mitretek (2001d).<sup>c</sup> Estimated on the basis of a campaign length of 87 operating days.

Solid effluents from the process would include caustic scrubber waste, spent anolyte-catholyte waste from agent treatment, spent anolyte-catholyte waste from energetics treatment, and primarily metals that have been treated to a 5X condition.

**Gas Effluents.** Off-gas from the MPT and BRT (mostly steam and  $\text{HNO}_3$ ) would be condensed in the SILVER II process for recovery or disposal. All process off-gas would be mixed with air and treated with a catalytic oxidation system.

In the facility ventilation system, these gases would pass through carbon filters prior to release to the atmosphere. This analysis assumed an off-gas treatment system consisting of six activated carbon beds and two HEPA filtration units in series. Handling and disposal of process residue in accordance with the provisions of RCRA are expected to result in little potential for significant adverse impacts on air quality. Emissions from vehicles and combustion of natural gas and LPG are regulated by the EPA and the State of Kentucky and are expected to result in little potential for significant adverse impacts on air quality. Dust emissions would be controlled during operations as well.

The electrochemical oxidation process would be required to meet RCRA and any other applicable environmental requirements and would operate under permit. The process would be required to destroy agent and energetic to a DRE of 99.9999% and to meet agent emission limits as established by the ASG. Other emissions, including metals, would be regulated in accordance with the RCRA permit. The operation would also be required to meet air pollution control requirements for conventional pollutants, such as  $\text{CO}$ ,  $\text{SO}_2$ , and opacity.

All ventilation air would be processed through carbon filtration before being released to the atmosphere. Facility effluent release points would include gaseous releases to the environment. Table 5.110 summarizes the facility effluent air release points.

Table 5.111 summarizes the estimated criteria pollutant emission rates during operations; these rates were estimated on the basis of the annual fuel consumption rates shown in Table 5.105. Daily emissions can be estimated from the hourly rates, assuming 12 operating hours per day.

Small amounts of organic and metallic compounds would be emitted from the combustion of natural gas during normal boiler operation and from the combustion of fuel oil during emergency diesel generator operation. Tables 5.112 and 5.113 summarize the TAP emission rates for the burning of natural gas in the boiler and fuel oil in the emergency diesel generator, respectively. Many of these emissions are also HAPs as defined in Section 112 of the CAA, Title III. The emission rates of these TAPs were estimated on the basis of the annual fuel consumption rates shown in Table 5.105 and with FIRE 6.22 emission factors for large wall-fired boilers with greater than 1,000 MMBtu/h of heat input and for reciprocating diesel engines (EPA 2000a). Daily emissions can be estimated from hourly rates, assuming 12 operating hours per day.

**TABLE 5.110 Stack Parameters for Electrochemical Oxidation at BGAD<sup>a</sup>**

Installation or Emission Point	Physical Stack Height (ft)	Stack Exit Diameter (ft)	Stack Exit Gas Flow (acfm)	Stack Exit Gas Velocity (ft/s)	Stack Exit Gas Temp (°F)	Stack Location <sup>b</sup>
Process steam boiler I <sup>b,c</sup>	70	0.8	1,681	60	325	Near southwest corner of PUB
Process steam boiler II <sup>b,c</sup>	70	0.8	1,681	60	325	Near southwest corner of PUB
Process steam boiler III <sup>b,c</sup>	70	0.8	1,681	60	325	Near southwest corner of PUB
Diesel generator exhaust I <sup>b</sup>	47	0.67	6,765	323	925	Near northwest corner of PMB
Diesel generator exhaust II <sup>b</sup>	47	0.67	6,765	323	925	Near northwest corner of PMB
Filter farm stack <sup>d,e</sup>	120	6.5	118,000	60	77	Center of structure

<sup>a</sup> Abbreviations: PMB = Personnel and Maintenance Building, PUB = Process Utilities Building, MDB = Munitions Demilitarization Building.

<sup>b</sup> Information on the stack characteristics for neutralization/SCWO was unavailable; characteristics similar to neutralization/biotreatment were assumed (Parsons/Allied Signal 1999).

<sup>c</sup> Stack exit gas flow for the process steam boiler taken from Parsons/Allied Signal (1999) and modified to take into account the annual average natural gas consumption rate of 188,000 scf/d for electrochemical oxidation.

<sup>d</sup> Stack characteristics similar to those at Newport, Indiana (PMCD 1999).

<sup>e</sup> Stack exit gas flow and diameter revised to account for 15% increase in the MDB proposed by the technology provider (AEA/CH2MHILL 2000).

The electrochemical oxidation facility at BGAD would be equipped with building ventilation systems that would discharge, to the atmosphere, indoor air from the MDB process area, the Laboratory Building, and the Personnel and Maintenance Building through the filter farm stack. Of the three ventilation systems, only the indoor air from the MDB process area would be potentially exposed to chemical agents during operations.

To estimate the maximum potential emissions of chemical agents, only the MDB process area was considered to be a significant potential source. The filter systems would be designed to remove chemical agents from the ventilation air streams to levels below the allowable stack concentrations that have been recommended by the U.S. Department of Health and Human Services, Centers for Disease Control (53 *Federal Register* 8504 – 8507, March 15, 1988). Also, a negative pressure would be maintained at all times in the MDB after initiation of hot operations to inhibit the release of chemical agents. Table 5.114 gives the potential chemical agent emission

**TABLE 5.111 Estimated Hourly and Annual Criteria Pollutant Emission Rates during Normal Operations of an Electrochemical Oxidation Facility at BGAD**

Criteria Pollutant	Process Steam Boiler Stack <sup>a</sup>		Diesel Generator Exhaust Stack <sup>b</sup>	
	lb/h	tons/yr	lb/h	tons/yr
CO	1.3	2.18	10.4	3.12
NO <sub>x</sub>	2.2	3.64	48.4	14.50
SO <sub>x</sub>	0.0	0.02	3.2	0.95
PM <sub>10</sub>	0.1	0.20	3.4	1.02
HC	0.1	0.14	4.0	1.18

<sup>a</sup> Estimated on the basis of the utility requirements listed in Table 5.105.

<sup>b</sup> Based on 600 hours of operations per year.

rates, assuming that the chemical agent concentrations in the air discharged would be at 20% of the recommended allowable stack concentrations (i.e., the level of quantification of the ventilation exhaust chemical agent monitors). These emissions calculations were based on actual operation time (12 hours per day, 276 days per year), since the only time there is a source of agent is during operations.

Tables 5.115 through 5.117 provide the estimated TAPs emission rates (lb/h) from the filter farm stack during operation for GB, VX, and mustard agent processing, respectively. Daily emission rates can be obtained by multiplying the hourly rates by 12. Annual emission rates can be estimated from the daily rates, assuming 232 operating days for GB (Table 5.115), 87 operating days for VX (Table 5.116), and 16 operating days for mustard agent (Table 5.117).

Emissions from operations worker commuter vehicles were estimated on the basis of the assumption that each of the operations workers (721) would drive a round trip consisting of two 20-mi (32-km) one-way trips per day. Table 5.118 gives the annual emission estimates due to the increased traffic.

**Liquid Wastes.** Liquid wastes would include dilute HNO<sub>3</sub> and sanitary wastes. The final PMACWA technology evaluation for electrochemical oxidation (PMACWA 2001b) notes that the technology provider proposes to route certain effluents to either a POTW or an on-site wastewater treatment plan, although the availability and acceptability of these disposal methods



**TABLE 5.112 Estimated Hourly and Annual TAP Emission Rates during Normal Boiler Operations for Electrochemical Oxidation at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
2-Methylnaphthalene	3.8E-07	1.2E-03
3-Methylchloranthrene	2.8E-08	9.4E-05
Acenaphthene	2.8E-08	9.4E-05
Acenaphthylene	2.8E-08	9.4E-05
Anthracene	3.8E-08	1.2E-04
Arsenic	3.1E-06	1.0E-02
Barium	6.9E-05	2.3E-01
Benz(a)anthracene	2.8E-08	9.4E-05
Benzene	3.3E-05	1.1E-01
Benzo(a)pyrene	1.9E-08	6.2E-05
Benzo(b)fluoranthene	2.8E-08	9.4E-05
Benzo(g,h,i)perylene	1.9E-08	6.2E-05
Benzo(k)fluoranthene	2.8E-08	9.4E-05
Beryllium	1.9E-07	6.2E-04
Butane	3.3E-02	1.1E+02
Cadmium	1.7E-05	5.7E-02
Chromium	2.2E-05	7.3E-02
Chrysene	2.8E-08	9.4E-05
Cobalt	1.3E-06	4.4E-03
Copper	1.3E-05	4.4E-02
Dibenzo(a,h)anthracene	1.9E-08	6.2E-05
Dichlorobenzene	1.9E-05	6.2E-02
Dimethylbenz(a)anthracene	2.5E-07	8.3E-04
Ethane	4.9E-02	1.6E+02
Fluoranthene	4.7E-08	1.6E-04
Fluorene	4.4E-08	1.5E-04
Formaldehyde	1.2E-03	3.9E+00
Hexane(n)	2.8E-02	9.4E+01
Indeno(1,2,3-cd)pyrene	2.8E-08	9.4E-05
Lead	7.8E-06	2.6E-02
Manganese	6.0E-06	2.0E-02
Mercury	4.1E-06	1.4E-02
Molybdenum	1.7E-05	5.7E-02
Naphthalene	9.6E-06	3.2E-02
Nickel	3.3E-05	1.1E-01
Pentane(n)	4.1E-02	1.4E+02
Phenanthrene	2.7E-07	8.8E-04
Propane	2.5E-02	8.3E+01
Pyrene	7.8E-08	2.6E-04
Selenium	3.8E-07	1.2E-03
Toluene	5.3E-05	1.8E-01
Vanadium	3.6E-05	1.2E-01

<sup>a</sup> Based on emission factors from EPA (2000a).

**TABLE 5.113 Estimated Hourly and Annual TAP Emission Rates during Emergency Diesel Generator Operations for Electrochemical Oxidation at BGAD<sup>a</sup>**

Compound	Hourly Emission (lb/h)	Annual Emission (lb/yr)
Acenaphthene	3.1E-07	1.9E-04
Acenaphthylene	1.1E-06	6.7E-04
Acetaldehyde	1.7E-04	1.0E-01
Acrolein	2.0E-05	1.2E-02
Aldehydes	1.5E-02	9.2E+00
Anthracene	4.1E-07	2.5E-04
Benzene	2.0E-04	1.2E-01
Benzo (a) anthracene	3.7E-07	2.2E-04
Benzo (a) pyrene	4.1E-08	2.5E-05
Benzo (b) fluoranthene	2.2E-08	1.3E-05
Benzo (g,h,i) perylene	1.1E-07	6.4E-05
Benzo (k) fluoranthene	3.4E-08	2.0E-05
1,3-Butadiene	8.6E-06	5.1E-03
Chrysene	7.8E-08	4.6E-05
Dibenzo(a,h) anthracene	1.3E-07	7.7E-05
Fluoranthene	1.7E-06	1.0E-03
Fluorene	6.4E-06	3.8E-03
Formaldehyde	2.6E-04	1.6E-01
Indeno(1,2,3-cd)pyrene	8.2E-08	4.9E-05
Isomers of xylene	6.3E-05	3.7E-02
Mercury	6.6E-08	4.0E-05
Naphthalene	1.9E-05	1.1E-02
Phenanthrene	6.5E-06	3.9E-03
PAHs	3.7E-05	2.2E-02
Propylene	5.7E-04	3.4E-01
Pyrene	1.0E-06	6.3E-04
Toluene	9.0E-05	5.4E-02

<sup>a</sup> Based on emission factors from EPA (2000a).

**TABLE 5.114 Estimated Maximum Hourly and Annual Agent Emission Rates from the Filter Farm Stack for Electrochemical Oxidation at BGAD**

Chemical Agent	Emission Factor (mg/m <sup>3</sup> ) <sup>a</sup>	Stack Exit Gas Flow (acfm) <sup>b</sup>	Hours of Operation per Year <sup>c</sup>	Stack Emission Rate	
				(lb/h)	(tons/yr) <sup>d</sup>
GB	0.00006	118,000	2,785	2.7E-05	3.7E-05
VX	0.00006	118,000	1,047	2.7E-05	1.4E-05
Mustard	0.006	118,000	194	2.7E-03	2.6E-04

<sup>a</sup> Based on the monitor level of quantification, which is 20% of the allowable stack concentration recommended for each chemical agent in 53 CFR 8504 – 8507.

<sup>b</sup> Filter farm stack exit flow based on estimated building ventilation for the MDB.

<sup>c</sup> Hours of operations based on the assumption that each pilot plant operates at the design throughputs specified in CBDCOM (1997).

<sup>d</sup> Estimate based on the number of hours of operation per year.

were not identified. These effluents would include those from a packaged batch fluoride treatment system, cooling tower blowdown, water softener, boiler blowdown, and sanitary wastewater.

**Solid Wastes.** The major process solid residuals expected from the electrochemical oxidation operation include the following:

- Scrap metal, dunnage, spent carbon garnet, and firing tubes that would be decontaminated to 5X primarily in the MPT or BRT;
- Decontaminated solid residues from the anolyte and catholyte circuits of the agent SILVER II process;
- Decontaminated solid residues from the anolyte and catholyte circuits of the energetics SILVER II process; and
- Wastes from the caustic scrubber circuits used in post-treatment.

**TABLE 5.115 Estimated TAP Emission Rates from the Filter Farm Stack during Electrochemical Oxidation of ACW Containing GB Agent at BGAD**

Compound	Emission Rate (lb/h)	Compound	Emission Rate (lb/h)
1,5-Pentanediol, dinitrate	4.3E-11	Hexadecane	9.5E-12
1-Butanol, 3-methyl-, nitrate	1.9E-10	Hexanenitrile	5.1E-12
1-Hexanol, 2-ethyl-	2.4E-12	Isopropyl nitrate	1.2E-09
2-Heptanone	4.4E-12	Naphthalene	2.6E-10
2-Hexanone	4.0E-11	Nitric acid esters	4.6E-11
2-Octanone	7.2E-12	Nitric acid, butyl ester	2.1E-10
2-Pentanol, nitrate	2.7E-10	Nitric acid, decyl ester	1.8E-11
4-Methyl-2-pentanone	1.8E-12	Nitric acid, ethyl ester	1.2E-10
4-Octene, (E)-	7.8E-13	Nitric acid, hexyl ester	1.2E-10
Acetamide, N,N-dimethyl-	1.4E-11	Nitric acid, nonyl ester	4.0E-11
Acetic acid	2.2E-11	Nitric acid, pentyl ester	1.2E-10
Acetone	1.3E-13	Nitric acid, propyl ester	1.3E-10
Benzene	1.5E-11	Nonanal	7.3E-12
Bis(2-ethylhexyl)phthalate	6.7E-12	Nonanenitrile	1.1E-11
Carbon disulfide	5.7E-10	Octanal	1.2E-11
Cyclotetrasiloxane, octamethyl-	2.9E-12	Octanenitrile	1.3E-11
Cyclohexane, 1,2,3-trimethyl-	2.7E-12	Pentadecane	1.9E-11
Decane	3.8E-11	Tetradecane	6.2E-11
Decanenitrile	6.6E-12	Toluene	4.0E-12
Dodecane	5.3E-11	Tridecane	5.5E-11
Ethylbenzene	1.0E-12	Undecane	4.7E-11
Heptanal	9.6E-12	Xylenes	5.5E-12
Heptanenitrile	5.7E-12		

These solid wastes would be transported to an approved off-site hazardous waste treatment, storage, and disposal facility for additional treatment and/or ultimate disposal. Table 5.119 shows the composition of the solid caustic scrubber waste and the rate of generation per processing day for processing of ACW containing GB, VX, or mustard agents. Tables 5.120 through 5.123 show the corresponding information for the processing of agent treatment spent anolyte-catholyte waste, energetics treatment spent anolyte-catholyte waste, 5X solids, and neutralized HNO<sub>3</sub>, respectively.

These waste streams would be shipped from the on-site facility to off-site locations. Tables 5.124 through 5.126 provide transportation data for annual shipment of these waste streams for mustard agent, GB, and VX processing on the basis of 16 operating days for mustard agent processing, 232 days for GB agent processing, and 87 days for VX agent processing.

**TABLE 5.116 Estimated TAP Emission Rates from the Filter Farm Stack during Electrochemical Oxidation of ACW Containing VX Agent at BGAD**

Compound	Emission Rate (lb/h)	Compound	Emission Rate (lb/h)
1,5-Pentanediol, dinitrate	3.9E-11	Hexanenitrile	4.7E-12
1-Butanol, 3-methyl-, nitrate	1.7E-10	Isopropyl nitrate	1.1E-09
1-Hexanol, 2-ethyl-	2.2E-12	MPA <sup>a</sup>	6.6E-17
2-Heptanone	4.0E-12	Naphthalene	3.3E-10
2-Hexanone	3.8E-11	Nitric acid esters	4.2E-11
2-Octanone	6.8E-12	Nitric acid, butyl ester	1.9E-10
2-Pentanol, nitrate	2.4E-10	Nitric acid, decyl ester	1.7E-11
4-Methyl-2-pentanone	2.2E-12	Nitric acid, ethyl ester	1.1E-10
4-Octene, (E)-	9.8E-13	Nitric acid, hexyl ester	1.1E-10
Acetamide, N,N-dimethyl-	1.3E-11	Nitric acid, nonyl ester	3.7E-11
Acetic acid	2.8E-11	Nitric acid, pentyl ester	1.1E-10
Acetone	1.7E-13	Nitric acid, propyl ester	1.2E-10
Benzene	1.4E-11	Nonanal	9.1E-12
Bis(2-ethylhexyl)phthalate	6.1E-12	Nonanenitrile	1.0E-11
Carbon disulfide	5.2E-10	Octanal	1.3E-11
Cyclohexane, 1,2,3-trimethyl-	3.4E-12	Octanenitrile	1.2E-11
Decane	3.6E-11	pentadecane	1.8E-11
Decanenitrile	6.2E-12	tetradecane	5.7E-11
Dodecane	5.0E-11	Toluene	3.6E-12
Ethylbenzene	9.6E-13	Tridecane	6.0E-11
Heptanal	9.1E-12	Undecane	4.4E-11
Heptanenitrile	5.2E-12	Xylenes	5.5E-12
Hexadecane	2.1E-11		

<sup>a</sup> MPA = methylphosphonic acid.

#### 5.3.5.4 Activities

The PMACWA described the activities for installation of the electrochemical oxidation system (PMACWA 2001b). The major phases of the project are shown in Table 5.127.

#### 5.3.5.5 Uncertainties

As indicated earlier, each of the individual technologies that form the electrochemical oxidation system has either been previously proven to be a successful technology or has been demonstrated by the PMACWA to be an acceptable technology for application at BGAD. However, demonstration testing focused on individual technologies and sometimes used less than full-scale units. In addition, although EDSs were conducted to evaluate the long-term adequacy of individual technologies, it was not possible to evaluate the long-term viability and performance of the entire, integrated treatment system. Thus, the primary uncertainty associated

**TABLE 5.117 Estimated TAP Emission Rates from the Filter Farm Stack during Electrochemical Oxidation of ACW Containing Mustard Agent at BGAD**

Compound	Emission Rate (lb/h)	Compound	Emission Rate (lb/h)
1,1-Dichloroethene	1.2E-11	Hexadecane	2.0E-13
2-Hexanone	1.1E-12	Isopropyl nitrate	6.1E-12
2-Octanone	2.6E-13	Methylene chloride	1.2E-11
4-Methyl-2-pentanone	8.2E-13	Naphthalene	1.2E-10
4-Octene, (E)-	3.7E-13	Nitric acid, decyl ester	4.3E-13
Acetic acid	1.1E-11	Nitric acid, nonyl ester	1.3E-12
Acetone	2.8E-11	Nonanal	3.4E-12
Carbon disulfide	1.7E-11	Nonanenitrile	3.8E-13
Chloroethane	2.6E-12	Octanal	2.3E-12
Chloroform	3.3E-12	Pentadecane	3.2E-13
Chloromethane	1.0E-11	Tetradecane	1.6E-12
Cyclohexane, 1,2,3-trimethyl-	1.3E-12	Trichloroethene	1.6E-11
Decane	1.5E-12	Tridecane	1.5E-12
Decanenitrile	3.0E-13	Undecane	1.6E-12
Dodecane	1.8E-12	Vinyl chloride	1.3E-11
Heptanal	4.2E-13	Xylenes	6.2E-13

**TABLE 5.118 Estimated Emissions from Worker Commuter Vehicles for Electrochemical Oxidation Operations at BGAD**

Criteria Pollutant	No. of Auto Round Trips <sup>a</sup>	Emission Factor (g/km) <sup>b</sup>	One-way Distance (mi) <sup>c</sup>	Emission Rate (tons/yr)
HC	199,000	1.16	20	16.4
CO	199,000	11.38	20	160.7
NO <sub>x</sub>	199,000	0.73	20	10.3
SO <sub>x</sub>	199,000	0.12	20	1.7
PM <sub>10</sub>	199,000	0.055	20	0.78

<sup>a</sup> Number of auto round trips to the operation site estimated on the basis of annual operating workforce and an assumption of 276 days of operation per year.

<sup>b</sup> Emission factors determined by using EPA modeling software MOBILE5b (EPA 2000c) for HC, CO, and NO<sub>x</sub> and PART5 (EPA 2000b) for PM<sub>10</sub>.

<sup>c</sup> One-way trip distance based on DOE (1997).

**TABLE 5.119 Estimated Generation Rates of Solid Caustic Scrubber Waste from Electrochemical Oxidation at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound <sup>a</sup>	Generation Rate (lb/d)		
	GB	VX	Mustard
(Carbethoxyethylidene) triphenylphos	9.8E-06	1.2E-05	2.1E-06
1,1'-Biphenyl, 4,4'-difluoro-	0.0E+00	0.0E+00	1.0E-06
1,2-Dichloroethane	0.0E+00	0.0E+00	1.6E-02
1-Butanamine, N-butyl-N-nitroso-	3.4E-04	0.0E+00	0.0E+00
2,4-Dinitrotoluene	4.5E-06	5.7E-06	9.7E-07
2-Butenoic acid, 4-nitrophenyl ester	0.0E+00	2.6E-02	0.0E+00
2-Nitrophenol	3.4E-04	7.3E-05	7.0E-02
2-Propanamine, N-(1-methylethyl)-N-nitro	1.9E-03	0.0E+00	0.0E+00
2-Pyrrolidinone, 1-methyl-	6.6E-05	6.0E-05	0.0E+00
3-Buten-2-one, 3-methyl	0.0E+00	3.6E-04	0.0E+00
Acetaldehyde	3.4E-04	0.0E+00	0.0E+00
Acetone	0.0E+00	1.0E-02	0.0E+00
Aluminum	2.1E-03	1.9E-03	1.8E-01
Benzene, 1-chloro-nitro- isomer	0.0E+00	0.0E+00	8.5E+00
Calcium	5.3E-01	4.8E-01	0.0E+00
Chloride	TBD <sup>a</sup>	TBD	1.2E-01
Chromium	6.9E-04	6.7E-04	2.6E-05
Copper	6.8E-05	8.5E-05	1.4E-05
Cyclohexanone	3.0E-04	2.7E-04	0.0E+00
DIPA	2.8E-04	0.0E+00	0.0E+00
EMPA	0.0E+00	1.6E-03	0.0E+00
Fluoride	0.0E+00	6.7E-01	0.0E+00
Formamide, N,N-dibutyl	4.1E-04	0.0E+00	0.0E+00
IMPA	1.6E+01	0.0E+00	0.0E+00
Iron	8.7E-04	1.1E-03	4.5E-01
Magnesium	6.3E-01	5.7E-01	0.0E+00
Mercury	6.7E-05	3.5E-05	0.0E+00
Methyl nitrate	1.4E-04	1.3E-04	2.3E-06
Molybdenum	5.3E-05	6.6E-05	1.1E-05
MPA	0.0E+00	1.4E-03	0.0E+00
Nickel	9.9E-04	1.2E-03	2.1E-04
Nitrate-N	1.4E+02	1.5E+02	7.1E-02
Nitric acid, 1-methylethyl ester	2.2E-01	2.0E-02	0.0E+00
Nitric acid, butyl ester	1.5E-03	0.0E+00	0.0E+00
Nitric acid, propyl ester	1.0E-03	0.0E+00	0.0E+00
Nitrite-N	1.2E+02	1.4E+02	2.5E-01
Nitrobenzene	0.0E+00	0.0E+00	1.6E+02
Nitropropane isomer	3.8E-03	0.0E+00	0.0E+00
n-Nitrosodimethylamine	6.9E-04	0.0E+00	0.0E+00
o-Phosphate-P	0.0E+00	0.0E+00	4.9E-01
Phenol	3.1E-05	0.0E+00	0.0E+00
Phenol, 2-fluoro-4-nitro- + unknown coelution	4.1E-04	0.0E+00	0.0E+00
Phosphorus	4.0E-03	6.5E-02	4.3E-05
Potassium	0.0E+00	0.0E+00	3.9E+00

**TABLE 5.119 (Cont.)**

Compound	Generation Rate (lb/d)		
	GB	VX	Mustard
Propane, 2-nitro	1.1E-03	0.0E+00	0.0E+00
Silver	1.8E-03	4.3E-05	2.4E-02
Sodium	6.1E+02	6.4E+02	2.0E+03
Sulfate	6.3E-02	9.6E-01	1.2E+02
Tributylamine	4.5E-02	0.0E+00	0.0E+00
Undecanoic acid	1.5E-06	1.9E-06	3.2E-07
Unknown alcohol	4.8E-02	1.1E-01	2.3E-02
Unknown aldehyde	0.0E+00	0.0E+00	2.6E-01
Unknown alkane	2.9E-03	6.2E-03	2.1E-03
Unknown alkene	2.9E-02	4.9E-02	9.7E+00
Unknown amine	4.5E-03	0.0E+00	0.0E+00
Unknown chlorinated hydrocarbon	0.0E+00	2.8E-06	1.1E-02
Unknown ketone	6.2E-03	1.9E-02	0.0E+00
Unknown organic acid	3.8E-02	1.9E-03	1.5E-01
Unknown PAH	1.2E-05	1.5E-05	2.6E-06
Unknown substituted alkane	2.6E-06	3.4E-03	5.6E-07
Unknown substituted alkene	1.7E-04	5.1E-03	3.7E-05
Urea, tetrabutyl-	2.1E-04	0.0E+00	0.0E+00
Water	5.2E+00	1.1E+01	1.4E+01
Total (lb/d)	8.9E+02	9.5E+02	2.3E+03
Operating days	232	87	16

<sup>a</sup> Abbreviations: DIPA = diisopropanolamine, EMPA = ethylmethylphosphoric acid, IMPA = isopropylmethylphosphoric acid, TBD = to be determined.

with electrochemical oxidation is that the entire, integrated treatment system, with all its component units, has not been assembled and tested. The pilot program, if implemented for this technology system, would be designed to evaluate overall operability and long-term performance.

### 5.3.6 DISMANTLING AND CLOSURE

The legislation that established the ACWA (Public Law 104-208) instructed the DOD to demonstrate alternatives to the baseline incineration process for the demilitarization of ACW. Subsequent legislation specified the continued management of the development and testing of technologies for the destruction of lethal chemical munitions. The status and disposition of ACWA pilot test facilities were not addressed in the legislation. An ACWA pilot facility could be (1) closed and decommissioned (i.e., operations terminated and the site secured) after the conclusion of testing; (2) converted to an operational chemical weapon destruction facility (this



**TABLE 5.120 Estimated Generation Rates of Solid Spent Anolyte-Catholyte Waste from Agent Treatment during Electrochemical Oxidation at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)		
	GB	VX	Mustard
1,2-Dichloroethane	0.0E+00	0.0E+00	2.5E-02
1,4-Oxathiane, 4,4-dioxide	0.0E+00	0.0E+00	4.7E-01
1-Butanamine, N-butyl-N-nitroso-	9.0E-03	0.0E+00	0.0E+00
1-Butane,2-(chloromethyl)-	0.0E+00	0.0E+00	1.4E-02
2-Butenal, 3-methyl	1.5E-03	0.0E+00	5.2E-03
2-Propanamine, N-(1-methylethyl)-N-nitro	0.0E+00	1.7E-01	0.0E+00
Propanamine, N-ethyl-N-nitroso-	0.0E+00	6.2E-03	0.0E+00
2-Propanamine, N-methyl-N-nitroso-	0.0E+00	4.1E-03	0.0E+00
3-Hexanol, 4-methyl-	0.0E+00	0.0E+00	2.0E-01
3-Hydroxy-3-methyl-2-butanone	4.9E-03	0.0E+00	0.0E+00
3-Methyl-3-chloro-1-butane	1.5E-03	0.0E+00	0.0E+00
Aluminum	2.9E+00	0.0E+00	4.8E-01
Arsenic	2.1E-03	0.0E+00	1.0E-02
Barium	7.3E-03	0.0E+00	0.0E+00
Benzene, 1-chloro-4-nitro-	0.0E+00	0.0E+00	1.1E-02
Chloromethane	0.0E+00	0.0E+00	8.1E-02
Chromium	0.0E+00	2.0E+01	0.0E+00
Cobalt	4.4E-01	9.8E-01	1.0E+00
Copper	1.6E-01	1.2E-01	9.1E-01
Diethylamine, 1,1-dimethyl-N-nitro-	0.0E+00	2.5E-02	0.0E+00
Diethylphthalate	5.7E-04	0.0E+00	0.0E+00
Diisopropylamine	0.0E+00	5.1E+00	0.0E+00
DIPA	0.0E+00	1.0E-01	0.0E+00
Fluoride	4.7E+01	0.0E+00	0.0E+00
Formamide, N,N-dibutyl-	1.5E-03	0.0E+00	0.0E+00
Glycerol tricaprylate	0.0E+00	7.3E-03	0.0E+00
Hexavalent chromium	3.7E+00	1.3E+01	1.2E+01
Iron	1.5E+01	8.8E+00	6.2E+01
Magnesium	4.0E-02	0.0E+00	0.0E+00
Manganese	3.1E-01	3.0E-01	1.2E+00
Mercury	1.6E-04	8.8E-05	5.5E-04
MPA	0.0E+00	4.1E+02	0.0E+00
Nickel	1.0E+01	4.3E+01	0.0E+00
Pentachlorophenol	0.0E+00	2.0E-03	0.0E+00
Phosphorus	8.3E+01	3.0E+02	0.0E+00
Selenium	5.9E-03	1.4E-02	0.0E+00
Silver	5.6E+02	4.6E+03	1.2E+04
Sodium	7.8E+00	0.0E+00	0.0E+00
Sulfate	8.9E+02	9.5E+02	3.4E+03
Unknown hydrocarbon	2.0E-03	0.0E+00	6.5E-03

**TABLE 5.120 (Cont.)**

Compound	Generation Rate (lb/d)		
	GB	VX	Mustard
Urea, tetrabutyl-	3.4E-03	0.0E+00	0.0E+00
Vanadium	4.3E-02	1.2E-01	0.0E+00
Vinyl chloride	5.6E-03	0.0E+00	2.8E-02
Water	7.7E+00	1.7E+01	2.7E+01
Zinc	1.0E-01	4.1E-02	4.0E-01
Total (lb/d)	1.6E+03	6.4E+03	1.5E+04
Operating days	232	87	16

option assumes that there would be chemical weapons remaining at the site); or (3) assigned functions other than the demilitarization of weapons in the chemical weapons stockpile (within the constraints imposed by the National Defense Authorization Act for Fiscal Year 2000). The latter two options, however, are beyond the scope of the ACWA EIS and this TRD. The future use of the current chemical weapons storage and related facilities is also beyond the scope of the ACWA EIS and this TRD. Only closure and decommissioning of an ACWA pilot facility can be addressed in the ACWA EIS and this TRD.

The closure and decommissioning of an ACWA pilot facility would require compliance with the provisions of any permits issued by regulatory agencies for the construction and operation of the facility. This would include compliance with RCRA requirements for the closure of a hazardous waste treatment, storage, or disposal facility. The PMACWA and other parties involved in the closure and decommissioning of an ACWA pilot facility also would have to meet U.S. Army and DOD requirements for managing and disposing of facilities involved in the handling of chemical warfare materials.

The closure and decommissioning of an ACWA facility would likely be similar to the closure of baseline incineration facilities (such as JACADS and TOCDF) and destruction facilities using alternative technologies (located at APG in Maryland and NCD in Indiana). The JACADS site closure plan (Washington 2000) and the APG and NCD RCRA permit applications (APG 1997 and NCD 1998a) contain general concepts for facility closure and decommissioning.

On the basis of the general requirements for a treatment, storage, or disposal facility under RCRA, U.S. Army, and DOD policies and regulations, and concepts for the decommissioning of chemical destruction facilities, the following steps would likely be involved in the closure and decommissioning of an ACWA pilot facility:

**TABLE 5.121 Estimated Generation Rates of Solid Spent Anolyte-Catholyte Waste from Energetics Treatment during Electrochemical Oxidation at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)		
	GB	VX	Mustard
1,3,5-Trinitrobenzene	4.5E+00	5.6E+00	2.1E+00
1,4-Dimethyl-4,5,7,8-tetrahydroimidazo-[	8.0E-01	1.0E+00	3.8E-01
1-propanone, 1-phenyl-, phenylhydrazone	3.7E-05	4.6E-05	7.8E-06
2,4,6-Trinitrotoluene	3.1E+00	3.9E+00	1.4E+00
2,4-Dinitrophenol	2.7E-05	3.4E-05	5.8E-06
2,4-Dinitrotoluene	2.5E-02	2.3E-02	0.0E+00
Aluminum	2.8E-02	2.5E-02	0.0E+00
Barium	4.4E-02	4.0E-02	0.0E+00
Benzenamine, 2,4,6-trinitro-	3.7E-03	4.7E-03	1.7E-03
Benzoic acid, 3,4,5-trimethoxy-2-notro-,	9.8E-05	1.2E-04	2.1E-05
Bicyclo[4,3.0]nona-3,7-diene, trans-	1.7E-03	2.2E-03	3.7E-04
Bis(2-ethylhexyl)phthalate	8.6E-04	9.3E-04	1.9E-04
Calcium	7.4E-01	6.8E-01	0.0E+00
Chromium	3.2E-02	3.4E-02	5.8E-03
Copper	7.4E-01	6.8E-01	9.6E-04
Cyclohexane, 1-methyl-2-propyl-	2.5E-03	2.3E-03	9.5E-06
Hexavalent chromium	8.5E-04	1.1E-03	1.8E-04
Iron	2.4E+00	2.2E+00	5.1E-02
Lead	2.3E+00	2.1E+00	0.0E+00
Manganese	8.5E-03	8.3E-03	6.4E-04
Nickel	2.2E-02	2.4E-02	4.2E-03
Pyridine, 1-acetyl-1,2,3,4-tetrahydro-5	1.8E-03	2.2E-03	3.8E-04
Salicylaldehyde, azine	2.5E-05	3.2E-05	5.4E-06
Silver	5.4E+01	6.8E+01	2.5E+01
Tetryl	4.2E+00	5.3E+00	1.9E+00
Unknown cyclic alkane	1.8E-03	1.7E-03	0.0E+00
Unknown hydrocarbon	9.1E-04	8.3E-04	0.0E+00
Water	2.1E+00	1.9E+00	3.2E-01
Zinc	1.4E-02	1.7E-02	6.4E-03
Total (lb/d)	7.5E+01	9.2E+01	3.1E+01
Operating days	232	87	16

**TABLE 5.122 Estimated Generation Rates of 5X Solids from Agent Treatment during Electrochemical Oxidation at BGAD To Be Sent Off-Site for Land Disposal or Recycling**

Compound	Generation Rate (lb/d)		
	GB	VX	Mustard
Steel body and other iron	5.6E+03	5.2E+03	5.8E+01
Aluminum	6.9E+01	1.5E+02	1.8E+03
Copper	8.2E+03	1.8E+04	7.8E+04
Zinc	6.3E+00	1.5E+01	3.2E+02
Glass fiber	8.6E+02	7.8E+02	0.0E+00
Total	1.5E+04	2.4E+04	8.0E+04
Operating days	232	87	16

- Removal of all hazardous wastes from the site;
- Decontamination of the structures and equipment (to include piping and tankage) to allow safe handling;
- Removal of all or part of the remaining equipment;
- Demolition of all or part of the facility;
- Removal or abandonment of all or part of the supporting infrastructure; and
- Grading and revegetation, as needed, of the areas after removal of structures and infrastructure.

These actions would generate wastes similar to those created during the operation of the facility. Wastes would include decontamination solutions consisting of water or caustic solutions containing agent and energetic by-products (similar to agent and energetic hydrolysates), contaminated and noncontaminated debris (such as metals, wood, and concrete that are similar to dunnage and maintenance wastes), protective clothing, wastes from administrative and maintenance areas, petroleum products, and industrial chemicals. To the degree feasible, these materials would be processed through the ACWA facility in the same manner as like materials during pilot testing. Once the facility is rendered nonoperational, these materials would be collected, containerized, and treated or disposed of in accordance with environmental regulations.

**TABLE 5.123 Estimated Generation Rates of Liquid Neutralized HNO<sub>3</sub> from Electrochemical Oxidation at BGAD To Be Sent Off-Site for Disposal or Treatment**

Compound	Generation Rate (lb/d)		
	GB	VX	Mustard
2,3,3-Trimethyl-1-hexene	5.6E-04	7.1E-04	1.2E-04
2,6-Dinitrotoluene	0.0E+00	2.4E-03	4.1E-04
Benzene, 1,4-dinitro-	6.5E-04	8.2E-04	1.4E-04
Benzene, 2-methyl-1,3,5-trinitro-	0.0E+00	5.7E-03	9.7E-04
Benzofurazan, 4-nitro	1.7E-03	2.2E-03	3.7E-04
Bis(2-ethylhexyl)phthalate	8.8E-04	8.0E-04	0.0E+00
Chromium	2.5E-04	3.2E-04	5.4E-05
Copper	6.1E-04	5.5E-04	0.0E+00
Decanoic acid	1.4E-03	1.3E-03	0.0E+00
Heptanoic acid	3.0E-03	2.8E-03	0.0E+00
Iron	8.2E-03	1.0E-02	1.8E-03
Lead	3.8E-03	4.8E-03	8.1E-04
NG	3.0E-03	2.8E-03	0.0E+00
Nitrate-N	6.0E-01	5.1E+00	1.0E+00
Nitrobenzene	3.0E-03	0.0E+00	0.0E+00
Nitrocellulose	2.6E-03	2.3E-03	0.0E+00
Nonanoic acid	2.2E-03	2.0E-03	0.0E+00
Octanenitrile	7.7E-04	7.0E-04	0.0E+00
Octanoic acid	3.4E-03	3.1E-03	0.0E+00
Pentanal, 2-methyl	1.8E-03	2.3E-03	3.9E-04
Silver	7.4E-02	9.3E-02	1.6E-02
Sodium	2.2E-01	1.9E+00	3.8E-01
Tetryl	1.2E+01	1.5E+01	2.6E+00
Unknown hydrocarbon	2.9E-03	3.1E-03	2.7E-04
Water	6.1E+01	5.7E+01	1.0E+02
Zinc	1.0E-03	1.3E-03	2.1E-04
Total (lb/d)	7.4E+01	8.0E+01	1.1E+02
Operating days	232	87	16

**TABLE 5.124 Transportation Data for Solid and Liquid Wastes from Electrochemical Oxidation of ACW Containing Mustard Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3	Output Material No. 4	Output Material No. 5
<b>Transported materials</b>					
Type/chemical	Scrubber waste	Spent anolyte-catholyte waste from agent treatment	Spent anolyte-catholyte waste from energetics treatment	5X solids – waste <sup>a</sup>	Neutralized HNO <sub>3</sub> waste
Physical form	Solid	Solid	Solid	Solid	Liquid
Chemical composition/temperature, pressure	See Table 5.119	See Table 5.120	See Table 5.121	See Table 5.122	See Table 5.123
<b>Packaging</b>					
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50	50
Material weight (lb)	450	1,370	1,370	450	470
Chemical content (wt%)	See Table 5.119	See Table 5.120	See Table 5.121	See Table 5.122	See Table 5.123
<b>Shipments</b>					
Average weight (tons/yr) <sup>b</sup>	18.6	123.0	0.3	648	0.9
Average volume (ft <sup>3</sup> /yr)	610	1,320	2.7	21,559	27
Packages/yr	83	180	1	2,933	4
Packages/shipment	48	28	28	48	48
Shipments/yr	2	7	1	62	1
<b>Form of transport/routing</b>					
Form of transportation	Truck	Truck	Truck	Truck	Truck
Destination – facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Treatment at POTW <sup>d</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

<sup>b</sup> Estimated on the basis of a campaign length of 16 days.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

<sup>d</sup> Depending on test results for hazardous constituents, off-site treatment at a POTW may be required.

**TABLE 5.125 Transportation Data for Solid and Liquid Wastes from Electrochemical Oxidation of ACW Containing GB Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No.2	Output Material No.3	Output Material No.4	Output Material No.5
Transported materials					
Type/chemical	Scrubber waste	Spent anolyte-catholyte waste from agent treatment	Spent anolyte-catholyte waste from energetics treatment	5X solids – waste <sup>a</sup>	Neutralized HNO <sub>3</sub> waste
Physical form	Solid	Solid	Solid	Solid	Liquid
Chemical composition/ temperature, pressure	See Table 5.119	See Table 5.120	See Table 5.121	See Table 5.122	See Table 5.123
Packaging					
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50	50
Material weight (lb)	480	1,110	1,510	450	500
Chemical content (wt%)	See Table 5.119	See Table 5.120	See Table 5.121	See Table 5.122	See Table 5.123
Shipments					
Average weight (tons/yr) <sup>b</sup>	102.7	189.2	8.7	1,713	8.6
Average volume (ft <sup>3</sup> /yr)	3,150	2,530	85.4	56,985	252
Packages/yr	429	345	12	7,751	35
Packages/shipment	48	28	24	48	48
Shipments/yr	9	13	1	162	1
Form of transport/routing					
Form of transportation	Truck	Truck	Truck	Truck	Truck
Destination – facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Treatment at POTW <sup>d</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the 5X solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

<sup>b</sup> Estimated on the basis of a campaign length of 232 days.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

<sup>d</sup> Depending on test results for hazardous constituents, off-site treatment at a POTW may be required.

**TABLE 5.126 Transportation Data for Solid and Liquid Wastes from Electrochemical Oxidation of ACW Containing VX Agent at BGAD**

Type of Data	Output Material No. 1	Output Material No. 2	Output Material No. 3	Output Material No. 4	Output Material No. 5
<b>Transported Materials</b>					
Type/chemical	Scrubber waste	Spent anolyte-catholyte waste from agent treatment	Spent anolyte-catholyte waste from energetics treatment	5X solids – waste <sup>a</sup>	Neutralized HNO <sub>3</sub> waste
Physical form	Solid	Solid	Solid	Solid	Liquid
Chemical composition/temperature, pressure	See Table 5.119	See Table 5.120	See Table 5.121	See Table 5.122	See Table 5.123
<b>Packaging</b>					
Type	55-gal drum	55-gal drum	55-gal drum	55-gal drum	55-gal drum
Container volume (ft <sup>3</sup> )	7.35	7.35	7.35	7.35	7.35
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	Varies	Varies	Varies	Varies	Varies
Container weight (lb)	50	50	50	50	50
Material weight (lb)	490	1,330	1,470	450	520
Chemical content (wt%)	See Table 5.119	See Table 5.120	See Table 5.121	See Table 5.122	See Table 5.123
<b>Shipments</b>					
Average weight (tons/yr) <sup>b</sup>	41.3	278.2	4.0	1,033	3.5
Average volume (ft <sup>3</sup> /yr)	1,260	3,080	40.0	34,355	99
Packages/yr	172	419	6	4,673	14
Packages/shipment	48	28	24	48	48
Shipments/yr	4	15	1	98	1
<b>Form of transport/routing</b>					
Form of transportation	Truck	Truck	Truck	Truck	Truck
Destination – facility type	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Land disposal <sup>c</sup>	Treatment at POTW <sup>d</sup>

<sup>a</sup> Review of the disassembly process indicates that the dimensions of the 5X solids would allow disposal in standard 55-gal drums. Further validation with the vendor may be required.

<sup>b</sup> Estimated on the basis of a campaign length of 87 days.

<sup>c</sup> Depending on test results for hazardous constituents, off-site disposal at a RCRA-permitted facility may be required.

<sup>d</sup> Depending on test results for hazardous constituents, off-site treatment at a POTW may be required.



**TABLE 5.127 Activities for  
Electrochemical Oxidation at BGAD**

Key Milestones
EIS start
Start of EDS-II testing
PMACWA programmatic EIS submittal
PMACWA programmatic ROD submittal
DOD technology decision
RCRA Part B and CAA permits approval
MDB construction start
MDB construction completion
Systemization/pilot test start
Systemization/pilot test completion
Operations start
Operations completion

Source: PMACWA (2001b).

Equipment removed from the facility would be decontaminated and reused or recycled when possible. Structures would be decontaminated to the degree required by U.S. Army and DOD regulations to allow their reuse or demolition. Demolition debris would be disposed of in accordance with environmental, U.S. Army, and DOD regulations.

Removal, demolition, grading, and revegetation operations would be similar to the activities during construction. Disassembly of the facility would involve equipment and actions very much like those used to prepare the site and to erect the facility. Materials used in the construction of the facility would be conveyed out of the area in a manner similar to that used to bring them into the area; for example, concrete and steel would be trucked away from the site. The area required to support removal and demolition operations would not exceed that needed for material staging and facility construction.

The operation of an ACWA facility would cease with the termination of pilot testing or the elimination of the chemical weapons stockpile. Unless the ACWA pilot facility was converted to some other use, closure and decommissioning would be unavoidable. Thus, both the potential positive and negative impacts of closure and decommissioning would be unavoidable.

### 5.3.7 COMBINATION TREATMENT TECHNOLOGIES

As indicated previously, the elements of the various unit operations could be combined into different but viable ACW treatment alternatives. Many different combination technologies may be considered. Supplemental information is not provided here for combination treatment

technologies. However, on the basis of information provided in Sections 5.3.2 and 5.3.3, it appears that system inputs and resource requirements, routine emissions and wastes, activities and schedules, and uncertainties would not differ appreciably from the basic systems described in this document.

## 5.4 REFERENCES

Aberdeen Proving Ground, 1997, *Application for Permit to Construct the U.S. Army Aberdeen Proving Ground Chemical Agent Disposal Facility*, Volume I, Aberdeen Proving Ground, Md., May.

AEA/CH2MHILL: See AEA Technology, Inc., and CH2MHILL, Inc.

AEA Technology, Inc., and CH2MHill, Inc., 2000, *Draft Final PMACWA Demonstration II Test Program for Assessment of Technologies for Assembled Chemical Weapons Demilitarization*, DAAM01-98-006, prepared for U.S. Department of Defense, Program Manager for Assembled Chemical Weapons, AEA Technology Engineering Services, Inc., Sterling, Va., Nov.

APG: See Aberdeen Proving Ground.

Carnes, S., 2001, personal e-mail from Sam Carnes, Oak Ridge National Laboratory, Oak Ridge, Tenn., to Marsha Goldberg, Argonne National Laboratory, Washington, D.C., and Penny Robitaille, U.S. Army, Program Manager for Chemical Demilitarization, Aberdeen Proving Ground, Md., March 13.

CBDCOM: See Chemical and Biological Defense Command.

Chemical and Biological Defense Command, 1997, *Assessment of Technologies for Assembled Chemical Weapon Demilitarization*, Solicitation Number DAAM01-97-R-0031, U.S. Army CBDCOM, Aberdeen Proving Ground, Md., July.

Dalton, D.W., 2000, *HD Hydrolysate Production for the Assembled Chemical Weapons Assessment Demonstration II and Engineering Design Studies Test Programs*, U.S. Department of Defense, Program Manager for Assembled Chemical Weapons Assessment, Aberdeen Proving Ground, Md., Nov. 3.

DOE: See U.S. Department of Energy.

Eco Logic: See ELI Eco Logic, Inc.

Edgewood Research, Development, and Engineering Center, 1996, *HD Hydrolysis/Biodegradation Toxicology and Kinetics*, ERDEC-TR-382, U.S. Army, ERDEC, Aberdeen Proving Ground, Md., Dec.

ELI Eco Logic, Inc., 1995, *The Eco Logic Gas-Phase Reduction Process for the Destruction of Bulk HD and VX Chemical Agent and Decontamination of Their Containers and Associated Material*, Rockwood, Ontario, Canada.

ELI Eco Logic, Inc., 2001, "Thermal Gas-Phase Reduction of Intractable Wastes," Environment Technology Case Studies Director [<http://www.eidn.com.au/ecologic.html>], accessed Feb. 6, 2001.

EPA: See U.S. Environmental Protection Agency.

ERDEC: See Edgewood Research, Development, and Engineering Center.

Folga, S.M., et al., 1999, *Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride: Storage of Depleted Uranium Metal*, ANL/EAD/TM-100, Argonne National Laboratory, Argonne, Ill., Sept.

Foster Wheeler/Eco Logic/Kvaerner, 2000, *Draft Final PMACWA Demonstration II Test Program Technical Report*, Foster Wheeler Corporation, Clinton, N.J., Nov.

General Atomics, 1999, *Assembled Chemical Weapons Assessment (ACWA) Draft Test Technical Report*, San Diego, Calif., June.

Lawrence Livermore National Laboratory et al., 1997, *Depleted Uranium Hexafluoride Management Program; the Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride*, UCRL-AR-124080, Volumes I and II, Revision 2, prepared by Lawrence Livermore National Laboratory, Science Applications International Corporation, Bechtel, and Lockheed Martin Energy Systems for U.S. Department of Energy, May.

LLNL: See Lawrence Livermore National Laboratory.

Mitretek: See Mitretek Systems, Inc.

Mitretek Systems, Inc., 2001a, *Estimates of Environmental Releases Associated with the Destruction of Assembled Chemical Weapons during Pilot Plant Testing of the Parsons/Honeywell Neutralization/Biotreatment Process*, McLean, Va., May.

Mitretek Systems, Inc., 2001b, *Estimates of Environmental Releases Associated with the Destruction of Assembled Chemical Weapons during Pilot Plant Testing of the General Atomics Neutralization/Supercritical Water Oxidation Process*, McLean, Va., May.

Mitretek Systems, Inc., 2001c, *Estimates of Environmental Releases Associated with the Destruction of Assembled Chemical Weapons during Pilot Plant Testing of the Foster Wheeler-Eco Logic-Kvaerner Neutralization/Supercritical Water Oxidation with Gas-Phase Chemical Reduction Process*, McLean, Va., May.

Mitretek Systems, Inc., 2001d, *Estimates of Environmental Releases Associated with the Destruction of Assembled Chemical Weapons during Pilot Plant Testing of the AEA Technology SILVER II Electrochemical Oxidation Process*, McLean, Va., May.

National Research Council, 1998, *Using Supercritical Water Oxidation to Treat Hydrolysate from VX Neutralization*, Committee on Review and Evaluation of the Army Chemical Stockpile Disposal Program, Board on Army Science and Technology, National Academy Press, Washington, D.C., Sept.

National Research Council, 1999, *Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons*, Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons, National Academy Press, Washington, D.C., Sept.

National Research Council, 2000, *Evaluation of Demonstration Test Results of Alternative Technologies for Demilitarization of Assembled Chemical Weapons, A Supplemental Review*, Committee on Review and Evaluation of Alternative Technologies for Demilitarization of Assembled Chemical Weapons, National Academy Press, Washington, D.C.

NCD: See Newport Chemical Depot.

Newman, K.E., 1999, *A Review of Alkaline Hydrolysis of Energetic Materials: Is It Applicable to Demilitarization of Ordnance?*, Report IHTR 2167, Naval Surface Warfare Center, Indian Head Division, Indian Head, Md. (as cited in NRC 1999).

Newport Chemical Depot, 1998a, *Application for Permit to Construct the U.S. Army Newport Chemical Depot Chemical Agent Disposal Facility*, Newport Chemical Depot, Ind., March.

Newport Chemical Depot, 1998b, *National Pollutant Discharge Elimination System Permit Application for the Department of the Army, Newport Chemical Depot, Newport Chemical Demilitarization Facility*, Newport Chemical Depot, Ind., May.

NRC: National Research Council.

Pacoraro, J., 1999, *Alternative Technologies and Approaches Project Overview*, Presentation to the Committee on Review and Evaluation on the Army Chemical Stockpile Disposal Program, Washington, D.C., Jan. 6 (as cited in NRC 1999).

Parsons/Allied Signal, 1999, *Assessment of Technologies for Assembled Chemical Weapons Demilitarization, Demonstration Test Final Report*, Pasadena, Calif., July.

PMACWA: See Program Manager for Assembled Chemical Weapons Assessment.

PMCD: See Program Manager for Chemical Demilitarization.

Program Manager for Assembled Chemical Weapons Assessment, 1997, *Report to Congress, Assembled Chemical Weapons Assessment Program*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., Nov.

Program Manager for Assembled Chemical Weapons Assessment, 1999a, *Final Technical Evaluation Report*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., Sept.

Program Manager for Assembled Chemical Weapons Assessment, 1999b, *Supplemental Report to Congress, Assembled Chemical Weapons Assessment Program*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., Sept.

Program Manager for Assembled Chemical Weapons Assessment, 1999c, *PMACWA Demonstration Test Data Quality Review Summary, General Atomics, Final Report*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., Sept.

Program Manager for Assembled Chemical Weapons Assessment, 1999d, *PMACWA Demonstration Test Data Quality Review Summary, Parsons/Allied Signal, Final Report*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., Sept.

Program Manager for Assembled Chemical Weapons Assessment, 2000a, *Dialogue on Assembled Chemical Weapons Assessment*, Materials presented in Portland, Ore., by U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., March 14–15.

Program Manager for Assembled Chemical Weapons Assessment, 2000b, *Notice of Intent (NOI), Environmental Impact Statement for Follow-On Tests, Including Design, Construction, and Operation of One or More Pilot Test Facilities for Assembled Chemical Weapon Destruction Technologies at One or More Sites*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., April 14.

Program Manager for Assembled Chemical Weapons Assessment, 2000c, *Supplemental Report to Congress, Assembled Chemical Weapons Assessment Program*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., Dec.

Program Manager for Assembled Chemical Weapons Assessment, 2001a, *Dialogue on Assembled Chemical Weapons Assessment*, Materials presented in Lexington, Ky., by U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., Jan.

Program Manager for Assembled Chemical Weapons Assessment, 2001b, *Final Technical Evaluation: AEA Technology/CH2MHILL SILVER II Electrochemical Oxidation, Foster Wheeler/Eco Logic International/Kvaerner Neutralization/GPCR-TW-SCWO Teledyne-Commodore Solvated Electron System*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., March.

Program Manager for Assembled Chemical Weapons Assessment, 2001c, *Supplemental Report to Congress, Assembled Chemical Weapons Assessment Program*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., April.

Program Manager for Assembled Chemical Weapons Assessment, 2001d, *PMACWA Demonstration II Data Quality Review Summary, PMACWA HD and Energetic Hydrolysate Production*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., March.

Program Manager for Assembled Chemical Weapons Assessment, 2001e, *PMACWA Demonstration II Data Quality Review Summary, Foster Wheeler*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., March.

Program Manager for Assembled Chemical Weapons Assessment, 2001f, *PMACWA Demonstration II Data Quality Review Summary, Eco Logic*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., March.

Program Manager for Assembled Chemical Weapons Assessment, 2001g, *Draft Environmental Impact Statement for the Design, Construction and Operation of One or More Pilot Test Facilities for Assembled Chemical Weapons Destruction Technologies at One or More Sites*, U.S. Department of Defense, PMACWA, Aberdeen Proving Ground, Md., May.

Program Manager for Chemical Demilitarization, 1988, *Final Programmatic Environmental Impact Statement (FPEIS) for Baseline Incineration*, U.S. Army, PMCD, Aberdeen Proving Ground, Md., Jan.

Program Manager for Chemical Demilitarization, 1997, *Revised Final Environmental Impact Statement for Disposal of Chemical Agents and Munitions Stored at Pine Bluff Arsenal, Arkansas*, U.S. Army, PMCD, Aberdeen Proving Ground, Md., Nov.

Program Manager for Chemical Demilitarization, 1998a, *Final Environmental Impact Statement for Pilot Testing of Neutralization/Biotreatment of Mustard Agent at Aberdeen Proving Ground, Maryland*, U.S. Army, PMCD, Aberdeen Proving Ground, Md., July.

Program Manager for Chemical Demilitarization, 1998b, *Final Environmental Impact Statement for Pilot Testing of Neutralization/Supercritical Water Oxidation of VX Agent at Newport Chemical Depot, Indiana*, U.S. Army, PMCD, Aberdeen Proving Ground, Md., Dec.

Program Manager for Chemical Demilitarization, 1999, *Preliminary Assessment of Health Impacts for the Newport Chemical Agent Disposal Facility*, 39-EJ-6788-99, U.S. Army, PMCD, Aberdeen Proving Ground, Md., Feb.

Program Manager for Chemical Demilitarization, 2000, *Notice of Intent (NOI), Blue Grass Army Depot Environmental Impact Statement*, U.S. Army, PMCD, Aberdeen Proving Ground, Md., Dec.

U.S. Army, 1997, *Department of the Army Pamphlet 385-61, Toxic Chemical Agent Safety Standards*, DA Pamphlet 385-61, Headquarters, Department of the Army, Washington, D.C., March.

U.S. Department of Energy, 1997, *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*, DOE/EIS-0200-F, Office of Environmental Management, Washington, D.C., May.

U.S. Environmental Protection Agency, 1994, *Eco Logic International Gas-Phase Chemical Reduction Process – The Reaction System: Applications Analysis Report*, EPA/540-AR-93/522, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, Sept.

U.S. Environmental Protection Agency, 2000a, *FIRE 6.22 for Windows® 95/98NT* [URL <http://www.epa.gov/ttn/chief/fire.html>].

U.S. Environmental Protection Agency, 2000b, *Highway Vehicle Particulate Emission Modeling Software “PART5,”* Office of Transportation and Air Quality [URL <http://www.epa.gov/otaq/part5.htm>].

U.S. Environmental Protection Agency, 2000c, *Vehicle Emission Modeling Software (MOBILE 5a, MOBILE5a-H, MOBILE 5b)*, Office of Transportation and Air Quality [URL <http://www.epa.gov/otaq/m5.htm>].

Washington Demilitarization Company, 2000, *JACADS Closure Campaign, Facility Closure Plan*, Hermiston, Ore., Oct.